A GENERAL VIEW

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OF THE

SCIENCES AND ARTS:

EQUALLY ADAPTED TO

DOMESTIC AND TO SCHOOL EDUCATION.

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IN TWO VOLUMES.

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INTRODUCTION.

A GENERAL view of the Sciences and Arts cannot but be both useful, and agreeable, to young persons, before they enter upon the study of them individually. Few, indeed, comparatively speaking, have time, opportunity, and ability to gain a complete knowledge of them all, and therefore such a view may be acceptable and beneficial to most. So great a progress has human intellect made in the Sciences and Arts which bless and embellish society, and so universal is their study become, that to be entirely ignorant of any one of their extensive circle, bespeaks want of education, want of good taste, want of generous emulation.

To give a concise, yet comprehensive account of them, is the purport of the following work. The plan is borrowed from that of Walker, set forth in his work entitled Archives of Science.

In studying the system of nature, that vast plan traced by the infinite wisdom, and accomplished by the unbounded power of the great First Cause, those objects should first be considered, which appear to be independent of any

others; namely, matter viewed generally, as to its motions and qualities; then, its chief forms of extension, the celestial orbs, the earth considered as a planet, and the laws which regulate them; next, the earth considered in a nearer and more particular view; the structure and history of those beings that occupy its surface, and the laws that regulate their existence; regarding man, as the chief of them, and considering the impressions which he receives from the various mineral, vegetable, and animal substances by which he is surrounded; with the ideas, emotions, and passions, they excite or generate in his mind; next, the various signs by which those impressions are communicated, and the mode of combining them; the effects that the use of those signs produces upon the conduct of individuals, and the deductions we form from the particular results of that conduct.

The description of the chief forms of matter, such as the celestial bodies, the earth considered as a planet, and of the laws which regulate them, is termed, General Physics, and comprehends the branches, named Astronomy and Cosmography, the former regarding the more distant orbs; the latter, our globe, as one of a system. The history of the earth more particularly considered, of the structure and habits of those beings which exist upon its surface, and the laws that regulate their existence, is termed Particular Physics, and comprehends Geography, Natural History; the anatomy of minerals, vegetables, and animals, as well as the remaining branches of Natural Philosophy; with Chemistry and Physiology. The re-

lation of the various signs by which the impressions that man receives from various surrounding objects, are communicated, and the different modes of combining them, comprehend literature and the Fine Arts. The detail of the effects produced by the use of those signs, and the deductions drawn from those various results, comprehend History, Biography, and Morals.

Following this scheme generally, but not exactly, we shall proceed to present to the youthful mind, a general view of the Sciences, and the Arts depending upon them. May this grand spectacle excite admiration and reverence towards that glorious unoriginated Being, who is the source of all existences, of all properties and qualities; of all vitality, of all intelligence.

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Page 3. line 22. *for* visable *read* visible.
5. line 11. *after the word* state *insert* and.
15. second line from the bottom, *for* gea *read* gaia.
15. second line from the bottom, *let* metreo *be in italics, and insert* to *after it.*
24. line 22. *for* qantity *read* quantity.
24. last line but one, *for* considered *read* considered as numbers.
89. after line 21. *add,* Ex. From 22. 6.
Take 4. 7325.
93. line 12. *instead of* 60—4. *read* 60 + 4.
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Page 39. line 9. *for* hand which *read* hand, &c. which.
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A

GENERAL VIEW

OF THE

SCIENCES AND ARTS.

CHAPTER I.

MATTER AND ITS PROPERTIES.

THE Sciences exhibit the amount of that knowledge of the objects and operations of nature, which the human mind has acquired.

By nature is meant the vast creation; the work of God, the supreme intelligence, the eternal self-existent, omnipresent, and immutable First Cause, infinitely powerful, wise, and good.

The Arts are the various applications of the Sciences, which men have made to their wants and comforts.

Universal Science may be arranged in six general divisions, subdivided into many particular branches.

The six general divisions of universal Science are, matter considered abstractedly, general

physics, particular physics, literature, morals, politics.

MATTER CONSIDERED ABSTRACTEDLY.

Metaphysics is that science which considers the facts and theories relative to matter, and which do not involve particular objects.

The original meaning of the word matter is, that something of which all things are made; which is the basis, the substratum of all forms and qualities; that which stands under, or supports, the various appearances that present themselves to our observation. Of this, human intellect, in its present limited state, knows little or nothing more than its properties.

Many philosophers have imagined all matter to be essentially the same, or homogeneous; and have thought that the innumerable varieties which appear in the objects around us, cognizable by our senses, proceed entirely from different combinations of particles of the same matter. Others have supposed that these differences proceed from particles of matter possessing different qualities.

The properties attributed to matter are, solidity, which includes extension and impenetrability, divisibility, moveability, inertness, or rest, attraction.

Solidity is length, breadth, and thickness, which, therefore, comprehends the idea of extension, that is, length and breadth, or form; and that of impenetrability, that is, the resist-

ance opposed by any one body, to the entrance of any other body, into the portion of space which it fills, until it has, itself, quitted that portion of space. By this property of impenetrability, or resistance, alone, we gain the idea of solidity. In this sense, solidity is a property common to all bodies, whether solid or fluid. It appears to be the most extensive property of matter, as being that by which we conceive it to fill space; and is distinguished from mere space, by the latter not being capable of resistance, or motion. Solidity, likewise, is distinguished from hardness, which is only a firm cohesion of solid particles. The difficulty of changing situation does not render the hardest body more solid than the softest. The diamond is not, properly, more solid than water.

Divisibility is a passive property in matter, whereby each particle is separable, either actually or mentally. Every extended corpuscle must have two sides, and, consequently, is divisable. We cannot conceive of a particle of matter, without the accompanying idea of its having two sides, or an upper and lower surface, and of the possibility of those surfaces, or sides, being divided. Though, therefore, the infinite divisibility of matter may be beyond human comprehension, yet it cannot be absolutely denied; for however minute a body may be, still we can form the conception of its being further divided. The subtilty of the particles of many bodies is such, as far to surpass our comprehension, and yet there are innumerable instances, in nature,

of such parts actually separated from one another.

Some faint idea of the wonderful divisibility of matter may be obtained, by considering that the smallest insect brought within reach of our vision by the microscope, and which would never have been visible to the human eye, without the aid of some such instrument, has organized parts, blood, and other fluids, necessary to the support of life.

Boyle measured leaf-gold, and found by weighing it, that 50 square inches weighed but two grains and a half. Now if the length of an inch be divided into 200 parts, the eye may distinguish them all; therefore there are, in one square inch, 40,000 visible parts; and in one grain of it there are 2,000,000 of such parts; which visible parts no one can deny to be farther divisible. Sixteen ounces of gold would completely cover a wire long enough to reach round our globe. The particles which, flowing from odoriferous bodies, excite the olfactory nerve, are so minute, that the loss of them produces no sensible diminution in the weight of those bodies, by which they are emitted. A lighted candle, placed on a plane, will be visible two miles, and, consequently, must fill a sphere, whose diameter is four miles, with luminous particles, before it has lost any sensible part of its weight.

In themselves, all bodies are quite indifferent as to motion, or rest. If a body were in a state of perfect rest, it would remain so for ever, did not acting power communicate to it motion. The capability of receiving such impulse, and of

being put into motion, is called the moveability, or mobility of matter. A body, once set in motion, would continue to move for ever, in the same direction, and with the same celerity, if not impeded by some extraneous cause. All matter is naturally in a state of rest, and its propensity to remain so is called the property of inertia, or rest. This is defined by Newton to be a power implanted in all matter, by which it resists any change endeavoured to be made in its state, whereby it becomes difficult to alter its state, either of rest or motion. Bodies exert this power only, in changes brought on their state by some force impressed upon them. The exercise of this power is, in different respects, both resistance and impetus, or impression. It is resistance, as the body opposes a force acting upon it to change its state, and impetus as the same body endeavours to change the state of the body acting upon it. The inertia of matter is a passive principle, by which bodies persist in their motion or rest; receive motion, in proportion to the force communicating it, and resist in proportion as they are resisted.

Attraction is the power or principle by which all bodies mutually tend towards one another. Of this power there are reckoned five kinds, or modifications.

The attraction of cohesion, by which particles of matter are held together in separate masses, thus forming the various detached bodies which we behold around us.

The attraction of combination, or chemical, or elective attraction.

The attraction of gravitation, by which all bodies on the surface of the earth are drawn towards, or tend towards its centre.

The attraction of magnetism.

The attraction of electricity and galvanism.

QUESTIONS.

What is the proper definition of the sciences? What is the proper definition of the arts? How may universal science be arranged? What is the science of metaphysics? What is the original meaning of the term matter? Is all matter supposed to be essentially the same? What properties are accounted common to matter in general? What is solidity, and what other qualities does it comprehend? What is the divisibility of matter? What is the moveability, or mobility, of matter? What is inertia, or rest? What is attraction?

CHAP. II.

METAPHYSICS.

SPACE. — PLACE. — MOTION. — DURATION. NUMBER.

Space is a simple idea, the modes of which are, distance, capacity, extension, figure, place, duration.

Distance, is space considered barely in length, between any two bodies.

Capacity, is space considered in length, breadth, and thickness.

Extension, is space, when considered as existing between the extremities of the matter

which fills its capacity. Hence it follows, that extension is an idea belonging to body only, while space may be conceived of, as separate from body.

Space, therefore, in its general signification, is the same thing as distance, contemplated in all directions.

Each different distance is a different modification of space, and each idea of any different space, is a simple mode of this idea. Such are, inch, foot, yard, and other measures of length; which are the ideas of certain stated lengths, settled by men for the purpose, and by the custom of measuring. When these ideas become familiar to the mind, they may be repeated at pleasure, without having the idea of body united with them. Thus men frame to themselves the ideas of feet, yards, fathoms, and other determined measures of distance, beyond the utmost bounds of all bodies; and by continually accumulating these, they can enlarge their idea of space as much as they please.

From this power of repeating and adding ideas of distance, without end, the idea of immensity is acquired.

Figure, is a modification of space, taken from the relation which the parts of the termination of extension, or circumscribed space, bear to one another. In sensible bodies, whose extremities come within our reach, this is discovered by the organ of touch, or feeling. It is discovered by the organ of vision, both from bodies, and colours, whose boundaries are within its sphere of action. By which instruments, the mind ob-

serving how the extremities terminate, whether in straight lines meeting at discernible angles, or in curved lines, in which no angles are perceptible, and considering all the relations of these to one another, in all parts of the extremities of any body, or of any portion of space, acquires the idea, we call figure; thus opening to itself an almost inexhaustible source of endless varieties of sensation. Hence originate the ideas of individual substances.

Place is that part of immoveable space which any body possesses.

By Aristotle, it is divided into internal place, or that portion of space which any body contains, and external place, or the space which includes, or contains that body.

Newton distinguishes place into absolute, or primary place; that part of infinite and immoveable space, which a body possesses; and relative or secondary place, the space which that body possesses, considered with regard to other adjacent objects.

Clarke adds another kind of relative place, which he calls relatively common place; and defines it to be, that part of any moveable, or measurable space which a body possesses; which portion of space moves together with the body.

According to Locke, the proper idea of place, is the relative position of any thing, with regard to its distance from certain fixed points; whence we say, that a thing has, or has not, changed place; when its distance is, or is not, altered with respect to those bodies.

With the idea of place, is intimately connected

that of motion. Motion is defined to be a continued and successive change of place, or the application of a body to different parts of infinite and immoveable space; or, the increase and diminution of relative distances; that is, the change of rectilinear distance between two points.

The ancient philosophers considered motion in a more general and extensive manner; for they defined it to be, a passage out of one state into another; and thus they reckoned six kinds of motion; creation, generation, corruption, augmentation, diminution, and lation, or local motion; the only one retained by the moderns.

Some divide motion into absolute and relative.

Absolute motion is the change of absolute place in any moving body; and its celerity therefore will be measured by the quantity of absolute space through which the moving body runs.

Relative motion is a change of the relative place of the moving body; and its celerity, consequently, is estimated by the quantity of relative space through which it runs.

Others divide motion into proper and improper.

Proper motion is a removal of a body out of one proper place into another; which thus becomes proper, as being possessed by this body alone, to the exclusion of all others. Such is the motion of a wheel in a clock.

Improper, extraneous, foreign, or common motion, is the passage of a body out of one common place into another common place. Such is that of a clock, when moving in a ship.

Motion is the subject of mechanics, and me-

chanics is the basis of all natural philosophy, which, from this circumstance, is denominated mechanical. In fact, all the phenomena of nature; all the changes which take place in the system of bodies, are owing to motion, and are directed according to its laws. Hence, modern philosophers have applied themselves with peculiar diligence to consider the doctrine of motion, and to investigate its properties and laws, by observation, experiment, and the use of geometry.

Duration is defined to be an idea obtained by attending to the fleeting, and perpetually perishing parts of any kind of succession.

The idea of succession is acquired by reflecting on the train of ideas which continually follow one another in our minds while we are awake. The distance between any parts of this succession, we call duration; and the continuance of the existence of ourselves, or of any other object commensurate to the succession of ideas in the mind, is called our own duration, or that of the object, co-existent with our thinking. So that we can have no idea of duration, when that succession of ideas ceases. According to Locke, duration is a mode, or modification of space.

Time is a portion of infinite duration. It is generally measured by motion, and principally by the motions of the heavenly bodies. When the mind has obtained the idea of duration by observing the succession of its thoughts, it naturally seeks to find some measure of this common duration, that it may be able to judge of its different lengths, and consider the distinct order

wherein several things exist, without which a great part of our knowledge would be confused, and a great part of history rendered very useless. This consideration of duration, as set out by certain periods, and marked by certain measures, may properly be called time. Such is the language of Locke on this subject. But probably there is nothing of which the mind is less capable of forming a distinct idea, than time unconnected with the motions of sensible objects.

Time is distinguished into absolute and relative.

Absolute time is time considered in itself, without any relation to bodies, or their motions flowing uniformly.

Relative time is the sensible measure of any portion of duration by means of motion.

Time is generally measured by motion, but not solely so; for the constant return of an event which happens, or of a thing which manifests itself, by intervals equally distant from each other, as the budding and flowering of plants, the arrival and departure of birds, may serve for a measure of time.

Time is usually represented by the uniform motion of a point that describes a right line. The point is the successive state; present, successively, at different places; and producing, by its flowing, a continual succession, to which we attach the idea of time. The uniform motion of an object also measures time. Thus in clocks, the hand moves uniformly in a circle; the twelfth part of the circumference of this circle is unity, and time is measured by this unity, by saying two hours, three hours, and so on. So likewise

one year is taken for one, because the apparent revolutions of the sun in the ecliptic are, to our senses, equal, or nearly so; and we therefore make use of it to measure other durations in relation with this unity.

There is no measure of time exactly correct. Every individual, has, in fact, his own measure of time, in the quickness or slowness with which his ideas succeed each other. The measures of time are arbitrary, and may vary among different people.

Number is properly a collection, or an assemblage of units, or of several things of the same sort. Some authors give a more comprehensive definition of number, calling it that by which any quantity is expressed. Numbers are divided into a variety of classes, according to the particular manner in which they are generated, or the forms under which they are included, or the properties which they possess.

A unit is the representation of any thing considered individually, without regard to the parts of which it may be composed.

An integer, or integral number, is a unit, or an assemblage of units.

An even number is that which can be divided into two equal integral parts.

An odd number is that which cannot be divided into two equal integral parts; being greater or less than some even number, by unity.

A composite number is any number that is produced by the multiplication of two or more integral factors. Or, it is a number that may be divided into two or more equal integral parts, each greater than unity.

A prime number, is a number which cannot be produced by the multiplication of any integral factors; or it is that, which cannot be divided into any number of equal integral factors.

Commensurable numbers are such as have each the same common divisor; or that may be, each, exactly divided into the same number of equal integral parts.

Incommensurable numbers, are such as have not a common divisor.

Square numbers, are those which arise from the product of two equal integral factors; as, forty-nine, produced by the multiplying together of two sevens; a hundred, produced by the multiplication together of two tens.

Cube numbers, are those which arise from the product of three equal integral factors; as, nine, the product of three threes; twenty-seven, the product of three nines.

A power, is that which arises from the multiplication of any number of equal factors; and it is called the second, third, fourth power, and so on, according as it consists of two, three, four, or more factors.

A perfect number, is that which is equal to the sum of all its divisors, or aliquot parts; thus, six is equal to one, added to two; and that added to three; one, two, and three, being all its divisors.

Abundant number, is that which exceeds the sum of all its divisors; as eight, which exceeds by a unit, the sum of all its divisors, one, two, four; which, added together, make only seven.

Deficient number, is that which is less than

the sum of all its divisors; as, twelve, the sum of whose divisors, one, two, three, four, six, is sixteen; greater than the number itself.

QUESTIONS.

What is the definition of space? And what are its modes? What is distance? What is capacity? What is extension? What is figure? What is place? How is place divided by Aristotle? How is place divided by Newton? What kind of place does Clarke add to the definition? What does Locke say of place? What is the definition of motion? How did the ancient philosophers consider motion? How is motion divided by different philosophers? Of what important science is motion the subject? How is duration defined? What is Locke's definition of duration? How is time defined by Locke and others? How is time distinguished? How is time measured? What is number? What is a unit? What is an integer? An even number? An odd number? A composite number? A prime number? Commensurable, and incommensurable number? What are square numbers? What are cube numbers? What is a power? What is a perfect number? What is abundant number? What is deficient number.

CHAP. III.

METAPHYSICS—continued.

MATHEMATICS—GEOMETRY.

From the two great trunks of the vast tree of Creation planted and upheld by the Almighty power of God, matter and space shoot forth various branches of science which bear those fruits of art that nourish the comfort and well being of man in his present state of existence.

From the two modifications of space, form and numbers, result the sciences of geometry and arithemetic, comprised under the generic term, mathematics. The name mathematics is derived from the Greek word *mathesis*, science, discipline.

Mathematics is that science which treats of the rates and comparison of quantities. It is defined by some, the "science of quantities," but by others more accurately, the "science of ratios," since quantities themselves are not the subject of mathematical investigation, but the ratio which such quantities bear to each other.

Mathematics are naturally divided into two classes; the one comprehending what is called pure and abstract mathematics; the other, what is styled, compound and mixed mathematics.

Pure mathematics relate to magnitudes, generally, simply, and abstractedly, and are therefore founded on the elementary ideas of quantity.—Mixed mathematics are certain parts of Physics, which are by their nature, capable of being submitted to mathematical investigation. To pure mathematics, therefore, belong geometry and arithmetic.

GEOMETRY.

Geometry is the science of extension, or extended things; that is, of lines, of surfaces, or of solids.

The term geometry is composed of two Greek words, *gea* or *gee*, earth; and metreo, measure; because the necessity of measuring the earth or

certain parts and portions of it, gave birth to the invention of the principles and rules of this science. Since its first invention, geometry has been so extended, and applied to such a variety of other objects, that, united with arithmetic, it is now become the general foundation of the mathematical science.

The Egyptians are supposed to have been the first inventors of geometry, and it is imagined that the annual inundations of the Nile, by sweeping away boundaries and landmarks, impelled them to turn their minds to this subject.

From Egypt the science of geometry was carried into Greece, where it was greatly cultivated and much improved by Thâles, Pythagoras, Anaxagoras, and Plato. About fifty years after the time of Plato, lived Euclid, who collected together all the theorems which had been invented by his predecessors in Egypt and Greece, and arranged them in fifteen books, entitled "the Elements of Geometry." The next after Euclid of those ancient writers on this science, whose works are preserved, is Apollonius Pergæus, and then, follows the famous Archimedes of Syracuse. During the period of European darkness, the Arabians paid great attention to the cultivation of this as well as the other sciences, and from them the mathematics were again received into various parts of Europe. Among more modern geometricians, the names of Des Cartes, Kepler, Leibnitz, Barrow, Newton, shine with peculiar lustre. The province of geometry is astonishingly extensive. To geometry may be referred astronomy, mechanics, music; all those sciences that con-

template things susceptible of addition and diminution; that is all the precise and accurate sciences. Geometrical lines and figures are not only proper to represent to the imagination the relations between magnitudes, or between things susceptible of more and less, such as spaces, times, weights, motions; but they may even represent to the mind things which it can conceive by no other means.

Geometry is commonly divided into four parts. Planimetry, altimetry, longimetry, and stereometry. Planimetry is that part of geometry which considers lines and plain figures, without any regard to heights, or depths. Thus it is restrained to the mensuration of planes or surfaces.

The art of measuring the surfaces and planes of things, is performed with the squares of long measures, as square feet, square inches, square yards; that is, by squares, whose sides are an inch, a foot, a yard; so that the area, or content of any surface is said to be found, when we know how many such square inches, feet, or yards, it contains.

Altimetry, is that part of geometry which is concerned in the measurement of altitudes, or heights, whether accessible, or inaccessible; including the doctrine and practice of measuring both perpendicular and oblique lines, whether in respect of height or depth.

Longimetry teaches to measure lengths, both accessible, such as roads; and inaccessible, such as arms of the sea.

Stereometry is that part of geometry which concerns the measuring of solid bodies: that is,

to find the solidity, or solid content of bodies, as globes, cylinders, cubes, vessels, ships, and similar bodies.

Geometry is distinguished, likewise, into theoretical and practical.

Theoretical geometry contemplates the properties of continuity, and demonstrates the truth of general propositions, called Theorems.

Practical geometry applies those speculations and theorems to particular uses in the solution of problems.

Theoretical geometry may be subdivided into elementary; which is occupied in the consideration of right lines and plain surfaces, and solids generated from them; and sublime, which is employed in the consideration of curve lines, conic sections, and bodies formed from them.

The science of geometry is founded upon certain axioms, or self-evident truths. It is introduced by definitions of the various objects which it contemplates, and the properties of which it investigates and demonstrates; such as points, lines, angles, figures, surfaces and solids. Lines are considered as straight or curved, and in their relation to one another, as inclined, parallel, or perpendicular.

Angles are considered as right, oblique, acute, obtuse, external, vertical.

Figures are considered with respect to their various boundaries, as triangles; as quadrilaterals; as multilaterals; as circles; and as solids.

DEFINITIONS AND AXIOMS OF GEOMETRY.

A solid has length, breadth and thickness.

A superficies, or surface, is one of the bounds of a solid, and has length and breadth without thickness.

A line is one of the bounds of a superficies, or surface, and has length, without breadth or thickness.

A point is one of the extremities of a line, and has neither length, breadth, nor thickness; neither parts, nor magnitude.

A right, or straight line, is that which lies evenly between its extreme points.

A plane surface, or superficies, is that which touches, in every part, any right line extended between points, any where taken in that surface.

An angle is the inclination, or opening of two right lines, meeting in a point. One right line is said to be perpendicular to another, when it makes the angles on both sides of it, equal to each other.

A right angle, is that which is made by the meeting of two right lines perpendicular to each other.

An acute angle, is that which is less than a right angle.

An obtuse angle, is that which is greater than a right angle.

A figure is that which is inclosed by one or more boundaries.

A circle is a plane figure, bounded by one line, called the circumference, which is in every part, equally distant from a point within the circle, called the centre.

Rectilineal figures are those which are contained by right lines.

Triangles are plane figures bounded by three right lines.

An equilateral triangle, is that which has all its sides equal to each other.

An isosceles triangle, is that which has only two of its sides equal to each other.

A right angled triangle, is that which has one right angle, and the side that is opposite to the right angle, is called the hypothenuse.

An obtuse angled triangle is that which has one obtuse angle.

Parallel right lines are such as are in the same plane, and which, being produced ever so far both ways, will never meet.

Every plane figure, bounded by four right lines, is called a quadrangle, or quadrilateral.

A parallelogram is a quadrangle, whose opposite sides are parallel.

The diagonal of a quadrangle is a right line joining any two of its opposite angles.

The base of any figure is that side upon which it is supposed to stand; and the vertical angle is that which is opposite to the base.

When an angle is expressed by means of three letters, the one which stands at the angular point must always be placed in the middle.

AXIOMS, OR SELF-EVIDENT TRUTHS.

Things equal to the same thing, are equal to one another.

If equals be added to equals, the wholes will be equal.

If equals be taken from equals, the remainders will be equal.

If equals be taken from unequals, the remainders will be unequal.

Things which are double of the same thing, are equal to one another.

Things which are halves of the same thing, are equal to one another.

The whole is equal to all its parts taken together.

Magnitudes which coincide, or fill the same space, are equal to one another.

The justness and accuracy of some of the foregoing definitions have been disputed, and others proposed to be substituted for them.

It is observed by Alexander Walker, that Euclid's definition of a point, as being " that which has no parts nor magnitude," is absurd; since not only is no character assigned to it, but the point is, hereby, deprived of all character; there is no difference betwcen it and nothing. Instead, therefore, of this definition, he proposes the following.

A point is that which has definite position, and relatively, small, but undefined, length, breadth, and thickness.

The definition of a line, according to Euclid, is, " that which has length without breadth."

To this, as evidently absurd, is substituted, " A line is that which has definite position and length, and relatively small, but undefined, breadth and thickness."

" A superficies, or surface," says Euclid, " is that which has only length and breadth." This definition is pronounced to be absurd, because that which has no thickness can have no length

or breadth, nor existence. The following definition is, therefore, offered in its place.

A superficies is that which has definite position, length and breadth, and, relatively small, but undefined thickness. And, according to these ideas, the definition of a superficies is, "That which has definite position, length, and breadth, and, relatively small, but undefined thickness."

Postulates, or things required to be allowed to be practicable.

That a right line may be drawn from any one given point to another.

That a right line may be produced, or continued out, at pleasure.

That a circle may be described from any point, as a centre, at any distance from that centre.

That a right line which meets one of two parallel right lines, may be produced till it meets the other.

QUESTIONS.

What is the science called mathematics? Whence is the term mathematics derived? Into what branches is the science of mathematics divided? To which branch of mathemathics, do geometry and arithmetic belong? What is geometry? What is the origin of the name geometry? Who were supposed to have been the first inventors of geometry, and what necessity gave rise to its invention? Whither was the science of geometry carried from Egypt? Who were the most celebrated ancient and modern geometricians? Is the province of geometry extensive? Into how many parts is geometry generally divided? What is altimetry? What is planimetry? What is longimetry? What is stereometry? How is measuring the surfaces and

planes of things performed? How is geometry farther divided? Upon what is the science of geometry founded; and how is it introduced? How are angles considered? How are figures considered? What is a solid? A line? A point? A right or straight line? A plane surface? What is an angle? A right angle? An acute angle? An obtuse angle? A figure? A circle? A triangle? What are the different kinds of triangles? What is the hypothenuse of a right angled triangle? What are parallel lines? What is a quadrangle? What is a parallelogram? What is the diagonal of a quadrangle? What is the base of any figure? When an angle is expressed by three letters, which must be in the middle? What are the principal axioms of geometry? Which of these definitions are doubted, and what definitions are proposed in their room? What are the chief postulates of geometry?

CHAP. IV.

GEOMETRY—continued.

Euclid pursued a most just and clear train of reasoning. He took nothing for granted, but such things as could not be denied; he rested upon no axioms which could be disputed; he made no postulates that could possibly be refused. The whole structure of his science is raised upon the strong basis of self-evident truths and demonstration.

Propositions, or things proposed to be done or demonstrated, are divided into theorems and problems.

A theorem is a proposition in which some truth is to be demonstrated.

A problem is a proposition in which some figure is to be constructed, and its truth proved.

Corollaries are inferences that follow from propositions already proved.

A lemma is something which is previously demonstrated, in order to render what follows more easy.

A scholium is a remark, or observation, made upon something going before it.

SIGNS OR CHARACTERS USED IN GEOMETRY.

The sign = signifies that the quantities between which it is placed are equal, as, $A = B$; that is A is equal to B.

To signify that A is less than B, the letters are written with this mark between them, $A<B$.

To express the idea of the quantity represented by A being greater than that which is expressed by B, they are thus written, $A>B$.

The sign + (plus) indicates that the quantities between which it is placed, are to be added together; thus $A+B$, expresses A added to B.

The character — (minus) placed between two letters signifies the excess of the qantity expressed by one of the letters above that expressed by the other; thus $A-B$ means the excess of the quantity called A above that called B.

These two last signs sometimes occur in the same sentence; as $A+B-C$, which means that C is to be subtracted from the sum of A and B.

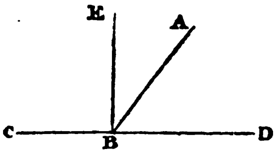
The sign $\times$, set between two quantities, means their product, if they be considered; but if they be regarded as lines, it signifies a rect-

angle, having those lines the boundaries of its length and breadth.

The expression A^2 means the square of the quantity A; and A^3 means the cube of A.

The sign $\surd$ indicates a root to be extracted thus $\surd A \times B$, means the square root of the product of A and B.

EXAMPLE OF A THEOREM.



A right line AB meeting another right line CD, makes with it two adjacent angles; which, taken together, are equal to two right angles.

At the point B in the right line CD, let BE be drawn perpendicular to CD. Then, the angle ABC is the sum of the angles CBE and EBA; therefore, ABC+ABD, is the sum of the three angles CBE, EBA, and ABD. The first of these, CBE, is a right angle, and the two others are together, equal to a right angle; therefore, the sum of the two angles ABC and ABD is equal to two right angles.

COROLLARIES.

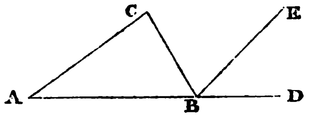
Hence it appears, first, that all the angles at the same point, B, on the same side of a right line, CD, are equal to two right angles; because every whole is equal to the sum of all its parts.

Secondly, that all the angles about any point as, B on the same side of a right line in which that point stands, are equal to two right angles.

Thirdly, that all the angles about the centre of a circle, are equal to four right angles.

THEOREM.

If one side, AB, of a triangle, ABC, be produced, the external angle CBD, will be equal to both the internal opposite angles, BAC, and BCA, taken together.



For let BE be drawn parallel to AC, then will the angle BCA, be equal to CBE (by the demonstrated theorem "that a line intersecting two parallel lines, makes the alternate angles equal to each other,") and the angle BAC will be equal to DBE (by a corollary drawn from the before-mentioned theorem, "that a line intersecting two parallel lines, makes the angles on the same side equal to each other,") and therefore the angle BCA, added to the angle BAC, will be equal to CBE and DBE; that is, equal to CBD, since every whole is equal to the sum of its parts.

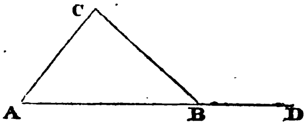
COROLLARY.

Hence, it follows that the external angle of a

triangle is greater than either of the internal, opposite, angles.

THEOREM.

The three angles of any plane triangle, ABC, taken together, are equal to two right angles.



For if AB be produced to D, then the angles BCA, and BAC, are equal to CBD, by the preceding theorem. To these equal quantities, let the angle CBA be added; then will C+A+CBA=CBD+CBA (by the axiom "if to equal things, equal things be added, the wholes will be equal) that is, equal to two right angles, by the theorem, "a line, standing upon an other line, makes with it two angles, which, taken together, are equal to two right angles."

COROLLARIES.

1. If two angles in one triangle, be equal to two angles in another triangle, the remaining angles will also be equal; by the axiom, "If from equal things, equal things be taken away, the remainders will be equal."

2. If one angle in one triangle, be equal to one angle in another, the sums of the remaining angles will be equal.

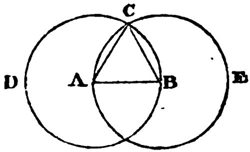
3. If one angle of a triangle be right, the other two taken together, will be equal to a right angle.

4. The two lesser angles of every triangle are acute.

5. Any angle in an equilateral triangle is equal to one third of two right angles, or two thirds of one right angle.

PROBLEM.

Upon a given finite right line, to describe an equilateral triangle.



Let AB be the given right line; and it is required to describe an equilateral triangle upon it.

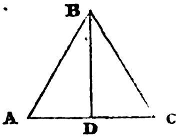
From the point A, at the distance AB, describe the circle, BCD; and from the point B, at the distance BA, describe the circle ACE. Then, because the two circles pass through each others' centres, they will cut each other. And if the right lines CA, CB be drawn from the point of intersection C, ABC will be the equilateral triangle required. For since A is the centre of the circle, BCD, AC is equal to AB; by the definition, that the circumference of a circle is every where equally distant from the

centre, and that all the radii of a circle being right lines drawn from the centre to the circumference, must be equal to one another. And, by the same definition, since B is the centre of the circle ACE, BC, also, is equal to AB. But things which are equal to the same things, are equal to one another; therefore AC is equal to CB.

And since AC, CB, are equal to each other as well as to AB, the triangle ABC, is equilateral; and it is described upon the right line AB, as was required to be done.

PROBLEM.

To bisect a given finite right line; that is, to divide it into two equal parts.



Let AC be the given right line; it is required to divide it into two equal parts.

Upon that given line, AC, describe (as directed by the foregoing problem) the equilateral triangle ACB, and bisect the angle ABC, by the right line BD; then will AC be divided into two equal parts, as was required. For AB is equal to BC, because an equilateral triangle has all its sides equal to one another; BD is common to each of the triangles ADB, and CDB; and

the angle ABD is equal to the angle CBD. But when two sides, and the included angle of of one triangle, are equal to two sides and the included angle of another, each to each, their bases will also be equal. The base AD, is, therefore, equal to the base DC; and consequently, the right line AC is bisected in the point D; the operation required.

QUESTIONS.

What are propositions, and how are they divided? What is a theorem? What is a problem? What are corollaries? What is a lemma? What is a scholium? What does this sign, = signify? What does this sign < mean? What does this character > express? What is the signification of this sign + ? What does this sign — denote? What does a figure, or number, prefixed to a letter expressive of a quantity, denote? How is it demonstrated that the angles made by one right line standing upon another right line are, when taken together, equal to two right angles? How is it demonstrated that, if one side of a triangle be produced, the external angle will be equal to both the internal opposite angles? How is it proved that the three angles of any plane triangle, taken together, are equal to two right angles? How is an equilateral triangle to be described upon a given finite right line? How may a given finite right line be bisected.

CHAP. V.

TRIGONOMETRY.

TRIGONOMETRY, a term derived from the two Greek words, *Trigonos*, triangle, and *Metron*, measure, signifies, literally, the measure of triangles; but it denotes, generally, that science

which relates to the determination of the sides and angles of triangles, from certain parts which are given. It may be regarded as the application of arithmetic to geometry.

It consists of two principal parts, namely,

Plane trigonometry, and spherical trigonometry.

Plane trigonometry treats of the application of numbers, to determine the relations of the sides and angles of any *plane* triangle, to one another.

Spherical trigonometry treats of the application of numbers, in like manner, to *spherical* triangles.

From its numerous and important uses, trigonometry may be considered as one of the most interesting branches of pure mathematics. Practical and physical astronomy, navigation, surveying, mechanics; almost every branch of the pure and mixed mathematics, excepting geometry and arithmetic, are connected with the principles of trigonometry. It is very uncertain when trigonometry began to be cultivated as a science; yet it is traced to Hipparchus, who flourished about 150 years before the Christian era. At nearly the close of the eighth century after the birth of Christ, an alteration was introduced into this science by the Arabians; that of computing by sines, instead of chords; who likewise added to it several axioms and theorems, which are considered as the foundation of modern trigonometry. About the middle of the 15th century, some change, and great additions, were introduced into this science, by Purbach, and Regiomontanus, Werner.

Copernicus, Rheinold, and Vieta, successively contributed to the advancement of the science, by useful alterations in the form of the tables for calculation, and by other improvements; and in more modern times, Napier, the inventor of logarithms, and Briggs.

In plane trigonometry, the circle is supposed to be divided into 360 equal parts, called degrees; every degree into 60 equal parts, called minutes; every minute into 60 equal parts, called seconds; and so on, into thirds, fourths, &c. These divisions are marked by the following characters, ° for degrees, ′ minutes, ″ seconds. As 29° 16′ 8″; that is, 29 degrees, sixteen minutes, eight seconds.

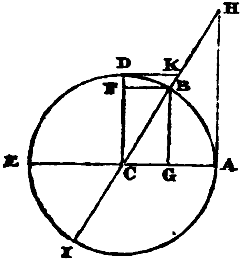
This division of the circle is, however, quite arbitrary, and any other number might have been employed instead of 360. The subdivisions, also, might have been formed upon any other scale, as well as the sexagesimal, or division by sixties; and accordingly the modern French mathematicians have adopted a different division. They suppose the circle to be divided into 400 degrees, or each quadrant, that is, each fourth part to consist of 100 degrees; the next subdivision is the 10th of a degree; the next, the 100th, and so on; and hence the measure of an angle is expressed by them, in the same manner as any other integral and decimal quantity.

Geometry demonstrates that any angles at the centre of a circle, have to one another, the same proportion, as the arches, or parts of the circumference intercepted between the lines which contain those angles, have to one another. Hence it is naturally inferred, that an angle at

the centre of a circle has the same ratio, or proportion to four right angles, which the arch, intercepted between the lines that contain the angle, has to the whole circumference. It also follows, that arches of a circle may be employed as measures of angles; and thus the comparison of angles, is reduced to the comparison of arches of a circle. From this principle, flow those definitions, upon which are constructed certain numerical tables; called trigonometrical tables, which are essential to the practice of both plain and spherical trigonometry.

TRIGONOMETRICAL DEFINITIONS.

1. If two straight lines intersect each other in the centre of a circle, the arch of the circumference intercepted between them, is called the measure of the angle which they contain. This explains what is meant by an angle subtending so many degrees. Thus, the arch AB is the measure of the angle contained by the lines CA and CH.



2. If the circumference of a circle be divided into 360 equal parts called degrees, each degree into 60 equal parts called minutes, and each minute into 60 equal parts called seconds; and so on; then, as many degrees, minutes, and seconds, &c. as are in any arch; so many degrees, minutes, seconds, &c. are said to be in the angle measured by that arch.

Corollary 1. Any arch is to the whole circumference of which it is a part, as the number of degrees and parts of a degree, in it, is to 360. And any angle is to four right angles, as the number of degrees and parts of a degree, in the arch which is the measure of the angle, is to 360.

Corollary 2. Hence also, it is evident, that the arches which measure the same angle, whatever be the radii with which they are described, contain the same number of degrees, and parts of a degree.

3. The supplement of an arch, or an angle, is, what that arch or angle wants of 180°; that is of a semicircle; thus the supplement of the arch DB, is DCI, the remaining part of the semicircle BEI.

4. The complement of an arch or angle, is, what that arch, or angle, wants of 90°, that is, of a quadrant; thus the complement of the arch BD, is BCA, the remaining part of the quadrant, DBA.

5. A sine or right sine of an arch, is a right line drawn from one extremity of that arch, perpendicular to the diameter touching the other

extremity. Thus BG is the sign of the arch AB, and of the angle ACB.

6. The versed sine of an arch, is that part of the diameter which is intercepted between its extremity and the sine. Thus, AG is the versed sine of the arch AB, or of the angle ACB.

7. The tangent of an arch, is a right line touching the circle, at one extremity of the arch, and meeting a diamcter of that circle passing through the other extremity of the arch. Thus AH, touching the circle at A, one extremity of the arch AB, and meeting the diameter CB, produced to H, after having passed, through B the other extremity of the arch AB, is the tangent of that arch, or of the angle ACB.

Corollary. The tangent of half a right angle is equal to the radius.

The secant of an arch is the diameter of the circle of which that arch is a part, which is produced to meet the tangent. Thus CH is the secant of the arch AB, or of the angle ACB.

The sine, tangent, and secant of any angle, as ACB, are also the sine, tangent and secant of its supplement, BCE. For, by the definition, BG is the sine of the angle BCE; and if BC be produced to meet the circle in I, then AH is the tangent, and CH the secant of the angle ACI, or BCE.

The sine, versed sine, tangent and secant of an arch, which is the measure of the angle, ACB, are to the sine, versed sine, tangent, and secant of any other arch which is also the measure of

the same angle, as the radius of the first arch is to the radius of the second arch.

Hence it appears that if tables be constructed, exhibiting, in numbers, the sines, tangents, and versed sines of certain angles to a given radius, they will exhibit the ratios, or relations, of the sines, tangents, and versed sines, of the same angles, to any radius whatever.

Such tables are constructed, calculated to a given radius for every degree, minute, and second of the quadrant.

The natural sines, tangents, cosines, &c. are calculated to a radius of 1, but the logarithmic sines, tangents, &c. are calculated to a radius of 10,000,000,000 or 1, with ten ciphers; so that the latter are the logarithms of the former, with ten, added to the index.

9. The cosine, cotangent, or cosecant of any angle, is the sine, tangent, or secant of the complement of that angle. Thus, supposing the angle ACD to be a right angle, then BF=CG, the sine of the angle BCD, is the cosine of the angle BCA; DK, the tangent of the angle, BCD, is the cotangent of the angle BCA; and CK, the secant of the angle BCD, is the cosecant of the angle BCA.

QUESTIONS.

What is trigonometry, and whence is the name derived? What are its two principal divisions? What is plane trigonometry? What is spherical trigonometry? What are the uses of trigonometry? Who, according to what is known of the matter, first cultivated trigonometry? By whom has trigonometry been successively improved? How does plane trigonometry suppose the circle to be divided?

Have any mathematicians divided the circle in a different way, than into 360°? What inference is drawn from the geometrical demonstration, that any angles at the centre of a circle, have to one another, the same proportion as the arches intercepted between the lines that contain the angle? What is the first definition in trigonometry? What is the second definition, and what corollaries flow from it? What is the supplement of any arch, or angle? What is the complement of any arch or angle? What is a sine, or right sine of an arch? What is the versed sine of an arch? What is the tangent of an arch? What is the secant of an arch? What proportion is there between the sine, versed sine, tangent, and secant of one arch which is the measure of a certain angle, and the same parts of any other arch which is also the measure of the same angle? What do trigonometrical tables exhibit, and to what are they calculated? What are the cosine, and cotangent, and cosecant of any angle?

CHAP. VI.

TRIGONOMETRY — continued.

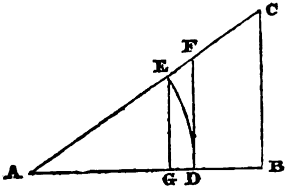
EXAMPLES OF THEOREMS IN PLANE TRIGONOMETRY.

Theorem.

In a right-angled plane triangle, as the hypothenuse is to either of the sides, so is the radius to the sine of the angle opposite to that side; and as either of the sides is to the other side, so is the radius to the tangent of the angle opposite to that side; or,

If, in a right-angled triangle, the hypothenuse

be made the radius, the sides become the sines of the opposite angles; and if one of the sides be made the radius, the other side becomes the tangent of the opposite angle, and the hypothenuse becomes its secant.



Let ABC, in the preceding figure, be a right-angled plane triangle, of which AC is the hypothenuse. On A, as a centre, with any radius, describe the arch DE; draw EG at right angles to AB, and draw DF touching the arch at D, and meeting AC in F. Then EG is the sine of the angle A, to the radius AD or AE; and DF is its tangent.

The triangles AGE, ADF, are manifestly similar to the triangle ABC. Therefore, AC is to CB, as AE is to EG; that is, AC is to CB, as the radius to the sine of the angle A.

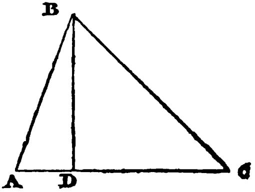
Again; AB is to BC, as AD is to DF. That is, AB is to BC as the radius is to the tangent of the angle A.

Corollary. In a right angled plane triangle, as the hypothenuse is to either of the sides, so is the secant of the acute angle adjacent to that side, to the radius.

For AF is the secant of the angle A, to the radius AD; and AC is to AB, as AF is to AD, that is AC is to AB as the secant of A, is to the radius.

Theorem.

The sides of a plane triangle are to one another as the sines of the opposite angles.



From any angle of a triangle, ABC, draw BD perpendicular to AC. Then, by the preceding theorem AB is to BD as the radius is to the sine of the angle A, and BD is to BC as the sine of the angle C, is to the radius. Therefore (as is proved by a geometrical proposition) inversely, AB is to BC, as the sine of the angle C, to the radius.

EXAMPLES OF THEOREMS IN SPHERICAL TRIGONOMETRY.

Theorem.

If a sphere be cut, by a plane, through the centre, the section is a circle.

The truth of this proposition is evident from the definition which geometry gives of a sphere.

A sphere is a solid figure, described by the revolution of a semi-circle about a diameter.

Definitions.

1. Any circle, which is a section of a sphere, by a plane passing through its centre, is called a great circle of the sphere.

Corollary. All great circles of a sphere are equal, and the centre of the sphere is their common centre, and any two of them bisect each other.

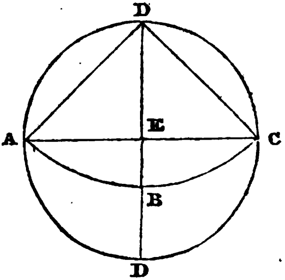
2. The pole of a great circle of the sphere is a point in the superficies of the sphere, from which all straight lines drawn to the circumference of the circle are equal.

3. A spherical angle is that which, on the superficies of a sphere, is contained by two arches of great circles, and is the same with the inclination of the planes of those great circles.

4. A spherical triangle is a figure, upon the superficies of a sphere, comprehended by three arches of three great circles, each of which arches is less than a semi-circle.

Theorem.

The arch of a great circle between the pole and the circumference of another circle, is a quadrant.



Let ABC be a great circle, and D its pole. Let the great circle ADC pass through D, and let AEC be the common section of the planes of the two circles, which will pass through E the centre of the circle ADC. Join DA, and DC. Because the chord DA is equal to the chord DC (by the second definition) the arch DA is equal to the arch DC. Now ADC is a semicircle; therefore the arches AD and DC are quadrants.

Corollary 1. If DE be drawn, the angle AED is a right angle; and DE, being, therefore, at right angles to every line it meets with in the plane of the circle, ABC is at right angles to that plane. Therefore the right line drawn from the pole of any great circle to the centre of the sphere, is at right angles to the plane of that circle.

Corollary 2. The circle has two poles D, D′, one on each side of its plane: which poles are the extremities of a diameter of the sphere perpendicular to the plane ABC.

ascribed to Plato himself. Others have assigned the honour of this discovery to Menechmus, a disciple of Eudoxus, and who flourished some little time after that of Plato.

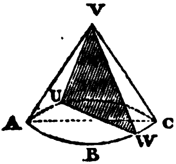
The writings of Archimedes, now extant, show, that the geometricians who had preceded him, had made considerable advances in investigating the properties of the conic sections; and his own discoveries in this branch of science, are worthy of his justly-merited fame. He determined the proportion of the elliptic spaces to the circle; and invented many propositions respecting the mensuration of the solids, by the revolution of the conic sections about their axes.

But from the writings of Apollonius of Perga in Pamphilia, the most information is derived, concerning the progress which his predecessors had made in the study of conic sections. He flourished in the reign of Ptolemy Philopater, about forty years later than Archimedes. His work on conic sections was held in such high estimation, that he was named the great geometer. Among modern writers on this subject, Dr. Wallis and Professor Playfair of Edinburgh stand distinguished.

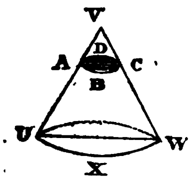
As conic sections are such curve lines as are produced by the mutual intersection of a plane, and the surface of a solid cone; it is evident that from different positions of the plane cutting the solid sphere, different figures will be formed. Of these figures, five are enumerated, namely, a triangle, a circle, an ellipse, a parabola, and an hyperbola.

When the cutting plane passes through the

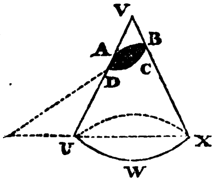
vertex or point of the cone, and any part of the base, the figure produced thereby, will be a triangle; as VUW, the section made by a plane passing through the vertex and part of the base of the cone, VABC, is evidently a triangle.



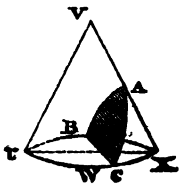
But if the intersecting plane cut the cone any where parallel to its base, or make no angle with it, the section made will be a circle; as the section made by the plane ABCD, passing through the cone VUXW, parallel to its base, is evidently a circle.



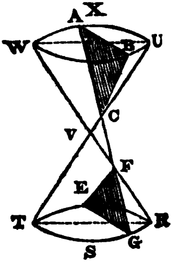
If the plane cut the cone obliquely through oth sides, that is, not parallel to its base, the figure formed by such a section, will be an ellipse; as in the cone VU WX, the section made by the plane ABCD passing obliquely through its sides is plainly an ellipse.



If the intersecting plane cut the cone in a situation parallel to one of its sides, it produces a figure called a parabola; as ABC, the intersecting plane, in the cone VUWX, is a parabola.

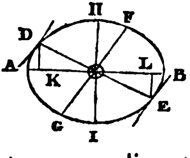


When the intersecting plane cuts the cone in such a manner, as to make a greater angle with the base, than the side of the cone does, it produces the figure, called an hyperbola. And if the plane be produced so as to cut an opposite cone in like manner, the latter section is called the opposite hyperbola to the former. Thus in the cone VWXU, the cutting plane ABC makes a greater angle with the base, than that which is made by the side of the cone, which figure is an hyperbola; to which EFG, in the other cone VTSR, is the opposite hyperbola.



Here, it is plain that the ellipse has two vertices, or summits, that opposite hyperbolas also have two vertices, but the parabola has only one vertex.

The vertices of any section are the points where the intersecting plane meets the opposite sides of the cone, as C and F in the last figure.



The axis, or transverse diameter of an ellipse is the line AB in the preceding figure.

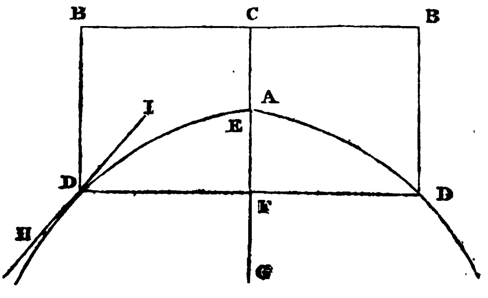
The centre of an ellipse is the middle of the

axis, (o). The centre of the hyperbola is without the curve, but in the parabola.

The centre is said to be infinitely distant from the vertex, because the diameter of the parabola may be considered as infinitely produced.

The diameter of an ellipse is a right line drawn through the centre and terminated on each side, by the curve, as DE, FG. The diameter of a parabola is a right line perpendicular to the directrix, terminated, at one extremity, by the parabola, and produced indefinitely within it; as EFG in the figure following.

If a right line BC and a point F without it, be given by position, in a plane; and a point D be supposed to move in such a manner, that DF its distance from the given point, is equal to DB its distance from the given line, the point D will then describe a parabola, DAD.



The right line BC, given by position, is called the directrix of the parabola.

The given point F is called the focus.

The point in which a diameter meets the parabola, is called the vertex of the parabola.

The diameter CF, which passes through the focus of a parabola, is called its axis, and the vertex of the axis, is called its principal vertex.

A right line terminated at each extremity by the parabola, and bisected by a diameter, is called an ordinate to that diameter, as DFD.

The conjugate to a diameter, is a right line drawn through the centre, and parallel to the tangent of the curve at the vertex of the diameter, as HI in the ellipse.

The segment of a circle, between its vertex and an ordinate, is called an absciss.

A right line quadruple the distance between the vertex of a diameter, and the directrix, is called a parameter, or latus rectum of that diameter.

A right line, meeting the parabola only in one point, and which every where else falls without it, is said to touch the parabola at that point, and is called a tangent to that parabola, as HI.

The ordinate to a diameter of an ellipse, is a line parallel to its conjugate, or to the tangent at its vertex, and terminated by the diameter and curve: thus DK, EL are ordinates to the axis AD, in the figure of the ellipse.

The ellipse and the hyperbola have each two foci, but the parabola only one.

QUESTIONS.

What are conic sections? Where does the discovery of conic sections appear to have originated? Who are the principal writers upon the subject of conic sections? What

are the different figures produced by different positions of the plane cutting the solid sphere? How is a triangle formed by the cutting plane? How is a circle formed by the intersecting plane? How is an ellipse formed by the cutting plane? How is a parabola formed by the cutting plane? How is the hyperbola produced by the intersecting plane? What are the vertices of any section? What is the axis, or transverse diameter of an ellipse? What is the centre of an ellipse, and where are the centres of the hyperbola and parabola? What is the diameter of an ellipse? How may a parabola be described? What is the focus of the parabola? What is the vertex of the diameter? What is the diameter of the parabola? What is the ordinate of the parabola? What is a conjugate to a diameter? What is an absciss? What is a parameter? What is a tangent? What is the ordinate to a diameter of an ellipse? How many foci have the ellipse and hyperbola? What foci has the parabola?

CHAP. VIII.

MENSURATION.—LAND SURVEYING.

Mensuration, in its most extensive signification, comprehends, as particular branches, geometry, trigonometry, algebra, conic sections, and even fluxions; but the term is more frequently used in a more confined sense, and is then applied to a system of rules and methods, by which numerical measures of geometrical quantities are obtained.

In all practical applications of mathematics, it is necessary to express magnitudes, of every kind, by numbers. For this purpose, a line of some determinate length, as one inch, one foot, and so on, is assumed as the measuring unit of lines; and the number expressing how often this

unit is contained in any line is the numerical value, or measure, of that line.

A surface, of some determinate magnitude, is assumed as the measuring unit of surfaces; and the number of units contained in any surface, is the numerical measure of that surface, and is called its area. It is usual to assume, as the measuring unit of surfaces, a square, whose side is the measuring unit of lines.

A solid, of a determinate figure and magnitude, is, in like manner, assumed as the measuring unit of solids; and the number of units contained in any solid is its solidity, or content. The unit of solids is a cube, each of whose edges is the measuring unit of lines; and, consequently, each of its faces is the measuring unit of surfaces.

A right angle is conceived to be divided into ninety equal angles; and one of these, called an angle of one degree, is assumed as the measuring unit of angles.

The measures generally employed in the application of mensuration to the common business of life, and their proportions to each other, are as follows:

TABLE OF LINEAL MEASURES.

12	Inches	=	1	Foot.
3	Feet	=	1	Yard.
6	Yards	=	1	Fathom.
5½	Yards	=	1	Pole, Rod, or Perch.
40	Poles	=	1	Furlong.
8	Furlongs	=	1	Mile.
69½	Miles	=	1	Degree.
360	Degrees	=		The Earth's Circumf.

TABLE OF SQUARE MEASURES.

144	Square inches	=	1 Foot square.
9	Square feet	=	1 Yard square.
30¼	Square yards	=	1 Pole ditto.
40	Square poles	=	1 Rood.
4	Roods, or 160 square poles,	=	1 Acre.
10	Square chains or 100,000 sqr. links,	=	1 Acre.
640	Square Acres	=	1 Square mile.

The Scotch acre is to the English acre, as 100,000 to 78,694.

TABLE OF SOLID MEASURES.

1728 Cubic inches	=	1 Cubic foot.
27 Cubic feet	=	1 Cubic yard.
282 Cubic inches	=	1 Ale gallon.
231 Do.	=	1 Wine gallon.
2150.42	=	1 Winchester bushel.
105 Cubic inches	=	1 Scotch pint.
The wheat firlot contains	=	21¼ Scotch pints.
The barley firlot	=	31 Scotch pints.

MENSURATION OF HEIGHTS AND DISTANCES.

By the application of geometry, the measurement of lines, which, on account of their position, or other circumstances, are inaccessible, is reduced to the determination of angles and of lines, which are accessible, and admit of being measured by well known methods.

A line, considered as traced upon the ground, may be measured with rods, or an instrument, called Gunter's chain of sixty-six feet; but still

more expeditiously, by measuring tapes of fifty, or a hundred feet.

By these, if the ground be tolerably even, and the direction of the line be traced pretty correctly, a distance may, by using proper care, be measured within about three inches of the truth, in every fifty feet; so that the error may not exceed the two hundredth part of the whole line.

Vertical angles may be measured with an instrument called a quadrant, furnished with a plummet and sights.

Fig. 1.

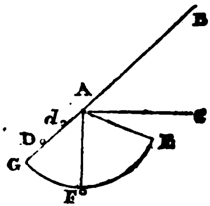
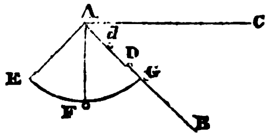


Fig. 2.



If an angle of elevation is to be measured, as the angle contained by a horizontal line AC, (Fig. 1.) and a line drawn from A to B the top of a tower or hill; or to a celestial body; the centre of the quadrant must be fixed at A, and the instrument moved about A in the vertical plane, till to an eye placed at G, the object B, be seen through the two sights D, d. Then will the arch EF, cut off by the plumb line AF, be the measure of the angle CAB.

An angle of depression CAB (Fig. 2.) is to be measured in the same manner, except that here

the eye is to be placed at A, the centre of the quadrant; and the measure of the angle is the arch EF.

The most convenient instrument for measuring angles, whether vertical or horizontal, is the theodolite. This instrument consists of a telescope and its level; a vertical arc; a horizontal limb, or plate, with a compass; which limb is generally about seven inches in diameter; and a staff with parallel plates. In the focus of the eye glass of the telescope, are two very fine wires or hairs, at right angles to each other, whose intersection is in the plane of the vertical arc. The vertical arc is firmly fixed to a long axis, which is at right angles to the plane of the arc.

This axis, sustained by and moveable upon, two supporters which are fixed firmly on the horizontal plate. On the upper part of the vertical arc are two brackets for holding the telescope; the inner sides of which brackets are so framed as to be tangents to the cylindric rings of the telescope, and, therefore, bear only on one part. One side of the vertical arc is graduated to half degrees, which are subdivided to every minute of a degree. On the other side of the vertical arc, are two ranges of divisions; one for taking the upright height of timber, in one hundredth parts of the distance between the instrument and the tree whose height is to be measured; and the other for reducing hypothenusal lines to such as are horizontal. The vertical arc is cut with teeth, or a rack, and may be moved regu-

larly and easily, by turning a milled nut fitted for that purpose. The compass is fixed to the upper horizontal plate; its ring is divided into 360 degrees, and the bottom of its box is divided into four parts or quadrants, each of which is subdivided to every ten. The magnetic needle is supported, in the middle of the box, upon a steel pin finely pointed; and there is a wire trigger for throwing off the needle when not in use. The horizontal limb consists of two plates, one moveable on the other. The outermost edge of the upper plate is marked so as to serve for an index to the degrees on the lower. The upper plate, together with the compass, the vertical arc, and telescope, is easily turned round by a pinion fixed to a screw. The horizontal plate is divided into half degrees, and numbered from the right hand towards the left. The divisions are subdivided to every minute of a degree. On the upper plate, are a few divisions similar to those on the vertical arc, giving the hundredth parts for measuring the diameter of trees, &c.

The whole instrument fits on the conical ferrule of a strong, brass-headed staff, which has three substantial wooden legs. The top or head of the staff, consists of two brass plates parallel to each other. Four screws pass through the upper plate, and rest on the lower plate, by the action of which, the horizontal limb may be set truly level. For this purpose, a strong pin is fixed to the outside of the plate, and connected with a ball that fits into a socket in the lower plate.

The axis of the pin and ball, are so framed as to be perpendicular to the plate, and, consequently. to the horizontal limb.

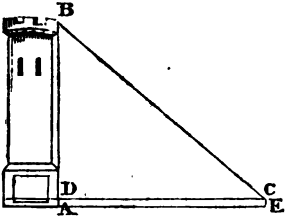
Three adjustments must be made, before the instrument is applied to the mensuration of angles. In the first place, care must be taken that the line of collimation (that is, the line of vision passing through the cross hairs) be exactly in the centre of the cylindric rings round the telescope; in the next place, that the level be parallel to this line; and, lastly, that the horizontal limb be so set, that when the vertical arc is at Zero, and the upper part moved round, the bubble of the level will remain in the middle of the open space.

When these adjustments are made, and the instrument is to be applied to practice, the lower plate of the horizontal limb, being supposed to remain unmoved and parallel to the horizon, the telescope is to be directed successively to the different objects, whose angular positions are to be determined by means of two pinions, of which, one turns the upper part of the instrument in a horizontal plane, and the other turns the arc in a vertical plane.

Then the angle which a line passing through the axis of the telescope and any object makes with the horizon, will be indicated by the arc of the vertical circle between 0° and the index engraved on the scale fixed to the upper plate of the horizontal limb of the instrument. Also, the horizontal angle, contained by two vertical planes, conceived to pass through any two objects and the centre of the instrument, will be shown by the arc of the lower plate of the horizontal

limb over which, the index, engraved on the upper plate, has passed by the direction of the telescope being changed from the one object to the other.

Example. — Having measured AE (in the following figure,) a distance of two hundred feet in a direct horizontal line, from the bottom of a tower, the angle, BCD, contained by the horizontal line, CD; and a line drawn from C to the top of the tower, having been measured by a quadrant, or by a theodolite placed at C, was found to be 47° 30′. The centre C of the instrument, was five feet above the line AE, at its extremity E. From these premises, it is required to determine AB, the height of the tower.



In the right angled triangle, CBD is given the side CD=200 feet, and the angle C=47° 30′. Then by the rules of plane trigonometry, the radius is to the tangent BCD, as DC is to DB. By employing the logarithmic tables, and proceeding as is taught by plane trigonometry, DB will be found to be equal to 218-3 feet. To which, if DA=CE=5 feet the height of the instrument, be added AB, the height of the tower will be found equal to 223-3 feet.

MENSURATION OF PLANE FIGURES.

Problem.

To find the area of a parallelogram, whether it be a square, a rectangle, a rhombus, or a rhomboid.

Rule 1. Multiply the length by the perpendicular breadth, and the product will be the area.

2. As the radius is to the sine of any angle of the parallelogram, so is the product of the sides including the angle, to the area of the parallelogram.

Problem.

Any two sides of a right angled triangle being given, to find the remaining side.

Rule 1. When the sides about the right angle are given, to find the hypothenuse. Add together the squares of the sides about the right angle, and the square root of the sum will be the hypothenuse.

2. When the hypothenuse, and one of the sides about the right angle, are given, to find the other side.

From the square of the hypothenuse, subtract the square of the given side; and the square root of the remainder will be the other side.

Problem.

To find the area of a triangle. Multiply any one of its sides by the perpendicular let fall upon it from the opposite angle, and half the product will be the area.

Problem.

To find the area of a circle.

Rule 1. Multiply half the circumference by half the diameter, and the product will be the area.

Rule 2. Multiply the square of the diameter by 7854, and the product will be the area.

Problem.

To find the area of an ellipse.

Multiply the product of the two axes, by the number 7854, for the area of the ellipse.

The foregoing problems seem sufficient to give some idea of the mensuration of plane figures.

LAND SURVEYING.

The instruments most commonly employed in land surveying, are the chain, the plane-table, and cross.

As a statute acre of land is 160 square poles, the measuring chain is made four poles, or sixty-six feet in length, in order that ten square chains, or 100,000 square links, may be equal to an acre. Hence, each link is 7·92 inches in length.

The plane-table is used for drawing plans of fields, and taking such angles as are necessary for calculating their areas. It is of a rectangular form, and is surrounded by a moveable frame, by means of which a sheet of paper may be fixed to its surface. It is furnished with an index, by which a line may be drawn on the paper in the direction of any object in the field; and with scales of equal parts, by which such lines may be made proportional to the distances of the objects from the plane-table when measured

by the chain; and its frame is divided into degrees for observing angles.

The cross consists of two pair of sights, set at right angles to each other, upon a staff, having a spike at the bottom to fix it firmly into the ground. Its use is, to determine the points where a perpendicular drawn from any object to a line, will meet that line. This is effected by making repeated trials till such a point be found in the line, as that when the cross is fixed over it so that one pair of the sights may be in the direction of the line, the object from which the perpendicular is to be drawn, may be seen through the other pair. Then the point, thus found, will be the bottom of the perpendicular.

A theodolite may, also, be applied to land surveying with great advantage, especially when the ground to be measured is of great extent.

In addition to these, there are other instruments employed in surveying; as the perambulator, which is used for measuring roads, and other great distances, where expedition is required more than accuracy. This instrument consists of a wheel, two feet seven inches and a half in diameter; and consequently half a pole or eight feet three inches in circumference. On one side of the axis, is a nut, three quarters of an inch in diameter, and divided into eight teeth, which when the wheel is moved round, fall into the eight teeth of another nut fixed on one end of an iron rod; and thus turn the rod once round, in the time the wheel makes one revolution. This rod, lying along a groove in the side of the carriage of the instrument, has, at its other end, a square hole, into which is fitted, the end

of a small cylinder. This cylinder is placed under the dial-plate of a movement at the end of the carriage, in such a manner as to be moveable about its axis. Its end is cut into a perpetual screw, which falling into the thirty-two teeth of a wheel, perpendicular thereto, upon driving the instrument forward, that wheel makes a revolution each sixteenth pole. On the axis of this wheel is a pinion with six teeth; which falling into the teeth of another wheel of sixty teeth, carries it round every one hundreth and sixtieth pole; or half a mile.

This last wheel, carrying a hand or index round with it over the divisions of a dial-plate whose outer limb is divided into one hundred and sixty parts, corresponding to the one hundred and sixty poles, points out the number of poles passed over. Again; on the axis of this last wheel is a pinion containing twenty teeth, which, falling into the teeth of a third wheel of forty teeth, drives it round once in three hundred and twenty poles, or a mile. On the axis of this wheel is a pinion of twelve teeth, which falling into the teeth of a fourth wheel, having seventy-two teeth, drives it round once in twelve miles.

This fourth wheel, carrying another index, over the inner limb of the dial-plate, divided into twelve, for miles, and each mile sub-divided into halves; quarters, and furlongs, serves to register the revolutions of the other hand, and to keep account of the half miles and miles passed over, as far as twelve miles.

Levels, with telescopic, or other sights, are used likewise, to determine how much any one place is higher or lower than another.

An offset staff is employed for measuring the offsets, and other short distances.

Ten small arrows, or rods of iron or wood, are used to mark the end of every chain length.

Pickets, or staves with flags, are set up as marks, or objects of direction.

Lastly, scales and compasses, are employed for protracting and measuring the plan upon paper.

The observations and measurements are regularly entered, as they are taken, in a book, called the Field-book; which serves as a register of all that is done, or that occurs in the course of the survey.

QUESTIONS.

What is mensuration? What is the measuring unit of lines? What is the measuring unit of surfaces? What is the area of a surface? What is the measuring unit of solids? What is the solidity or content of a solid body? Into how many angles is a right angle supposed to be divided? What is the table of lineal measures? What is the table of square measures? What is the table of solid measures? How may lines traced upon the ground be measured? By what instrument may vertical angles be measured? What is the most convenient instrument for measuring angles? What is the rule for finding the area of a parallelogram? What is the rule for finding the area of a triangle? How is the area of a circle to be found? How do you find the area of an ellipse? What instruments are used in land surveying?

CHAP. IX.

MENSURATION OF SOLIDS.

A SOLID is a figure which has length, breadth and thickness; and its measure is called its solidity, capacity, or content. Solids are measured by cubes, whose sides are yards, feet, inches.

A prism is a solid whose ends are any plane figures which are equal and similar, and whose sides are parallelograms.

A cube is a square prism having six sides, which are all equal, and squares.

The solidity of a cube is found by multiplying the area of the base by the height.

A cylinder is a round prism, which has two equal circles for its ends. The rule for finding its contents, is, multiply the diameter of its end by 3.1416, which gives its circumference; multiply this by 7854, which gives the area of the base; and this product, multiplied by its height, gives the solid contents.

A pyramid is a solid, whose sides are triangles meeting in a point at the summit; and the base is any plane figure.

The rule for finding the contents of a pyramid, is, multiply the base by the perpendicular height, and take one third of the product.

A sphere is a solid, bounded by one continued convex surface, every point of which is equally distant from a point within, called the centre.

Rule for finding the surface of a sphere or any segment or zone thereof.

Multiply the circumference of the sphere by the height of the part required, and the product will be the curve surface; whether it be a segment, a zone, or a whole sphere.

The height of the whole sphere is its diameter.

To find the solidity of a sphere.

Rule. — Multiply the area of a great circle of the sphere by its diameter, and take two thirds of the product for its content.

Multiply the cube of the diameter by the decimal .5236, for the content.

To find the solid content of a paraboloid, or solid, produced by the rotation of a parabola about its axis.

Rule.—Multiply the area of the base by the height, and take half the product for the content.

To find the solid content of a hyperboloid, or solid, generated by the rotation of a hyperbola about its transverse axis.

Rule.—As the sum of the transverse axis, and the height of the solid, is to the sum of the said transverse axis and two thirds of the height, so is half the cylinder of the same base and altitude, to the solidity of the hyperboloid.

GAUGING.

Gauging teaches the method of measuring casks, and other vessels and packages that fall under the cognizance of the officers of the excise. It derives its name from a rod, called a gauge, used for this purpose.

From the way in which casks are constructed, they are evidently solids of no determinate geometrical figure.

It is, however, usual to consider them as having one or other of the four following forms.

1. The middle frustum of a spheroid.
2. The middle frustum of a parabolic spindle.
3. The two equal frustums of a paraboloid.
4. The two equal frustums of a cone.

The principal rules laid down for the conducting of this kind of mensuration, are as follows:

Problem 1.

To find the content of a cask of the first or spheroidal middle frustum.

Rule.—To the square of the head-diameter, add double the square of the bung-diameter, and multiply the sum by the length of the cask. Then let the product be multiplied by $.0009\frac{1}{4}$, or divided by 1077, for ale gallons; or multiplied by $.0011\frac{1}{3}$, or divided by 882, for wine gallons.

Problem 2.

To find the content of a cask of the parabolic spindle form.

Rule.—To the square of the head-diameter, add double that of the bung-diameter: and from the sum, take $\frac{2}{5}$ or $\frac{4}{10}$ of the square of the difference of the said diameters. Then, multiply the remainder by the length of the cask; and the product, multiplied by $.0009\frac{1}{4}$, or divided by 1077 for ale gallons, or multiplied by $.0011\frac{1}{3}$, or divided by 882, for wine gallons, will give the content.

Problem 3.

To find the content of a cask of the third, or paraboloidal form.

Rule.—To the square of the bung-diameter, add the square of the head-diameter, and multiply the sum by the length of the cask. Then, if the product be multiplied by .0014, or divided by 718, the result will be the content in ale gallons. Again, if the product be multiplied by .0017, or divided by 588, the result will be the content in wine gallons.

Problem 4.

To find the content of a cask of the fourth or conical form.

Rule.—To three times the square of the sum of the bung and head-diameters, add the square of the difference of those diameters. Multiply that sum by the length of the cask, and multiply the result by $.00023\frac{1}{5}$, or divide it by 4308, for the content, in ale gallons; or multiply the result by $.0028\frac{1}{3}$, or divide it by 3529, for the content in wine gallons.

As these four forms of casks are merely hypothetical, some degree of uncertainty must attend the application of these rules to actual measurement. The following rule, laid down by Dr. Hutton, will apply to the measurement of any cask whatsoever.

Rule.—Add into one sum, thirty-nine times the square of the bung-diameter, twenty-five times the square of the head-diameter, and twenty-six times the product of the diameters; multiply the sum by the length of the cask, and the product .00034; then, the last product, divided by nine, will give the wine gallons, and divided by eleven, will give the ale gallons.

QUESTIONS.

What is a solid, and how are solids measured? What is a prism? What is a cube, and how is its solidity found? What is a cylinder, and what is the rule for finding its content? What is a pyramid, and by what rule is its content found? What is a sphere, and how is its content to be found? What is the rule for finding the surface of a sphere? What is a paraboloid, and how is its solid content to be found? What is a hyperboloid, and by what rule is its solid content to be found? What is gauging? How

many forms of casks are supposed? What is the general rule laid down by Dr. Hutton, applicable to the measuring casks of all forms?

CHAP. X.

ARITHMETIC.

ARITHMETIC, a term derived from the Greek word, arithmos, number, is the science which explains the properties of numbers, and shows the method or art of computing by them. This science must have existed, to a certain degree, in the earliest ages; for it is hardly possible to conceive that any nation, or indeed any individual endowed with reason, could be absolutely without knowledge of the difference between greater and smaller numbers. Yet it is possible that mankind may have subsisted in society, for a long time, without bringing this science near to perfection. The Mosaic history seems to prove, that immediately after the Deluge, if not before that dreadful event, some knowledge of arithmetic must have prevailed. The directions given to Noah concerning the dimensions of the ark, leave no room to doubt of his having been acquainted with numbers and measures. The Greeks appear to have been the first of the European nations that paid any great attention to arithmetic. They made use of the letters of their alphabet to represent their numbers. The twenty-three letters taken according to their order, at first denoted the numbers, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 20, 30, 40, 50, 60, 70, 80, 100, 200, 300, 400, 500, 600, 700 and 800, to which they added three other characters, to represent 6, 90, and 900. The

Romans followed a similar method, and besides characters for each rank of classes, they introduced others, for five, fifty, and five hundred. Their numeral letters and values are the following,

I. V. X. L. C. D.
one, five, ten, fifty, one hundred, five hundred,
M. one thousand.

By combining and repeating, according to the following rules, any number, however great, may be represented.

1. When the same letter is repeated twice, or oftener, its value is represented as often; thus II, signifies two; XX, twenty; XXX, thirty; CC, two hundred.

2. When a numeral letter of lesser value is placed after one of greater value, their values are added; thus, XI, signifies eleven; LII, fifty two; MDCXI, one thousand, six hundred, and eleven.

3. When a numeral letter of inferior value is placed before one of greater value, the value of the lesser is taken from that of the greater. Thus, IV, signifies four; IX, nine; XL, forty; XC, ninety; CD, four hundred. Sometimes IↃ is used for five hundred, instead of D, and the value is increased ten times by annexing Ↄ to the right hand. Thus, IↃ, five hundred; IↃↃ, five thousand; IↃↃↃ, fifty thousand.

Sometimes thousands are represented by drawing a stroke over the top of the numeral, as, $\overline{\mathrm{V}}$, five thousand; $\overline{\mathrm{L}}$, fifty thousand; $\overline{\mathrm{C}}$, one hundred thousand.

About the year of our Lord, 200, a new kind of arithmetic, called sexagesimal, was invented by Claudius Ptolemus. In this kind of arith-

metic, every unit was supposed to be divided into sixty parts, and each of these into sixty others, and so on. Hence any number of such parts were called sexagesimal fractions; and to render the computation in whole numbers more easy, the progression of these was also made to be sexagesimal. Thus, from one to fifty-nine, were marked in the common way; then, sixty was called a sexagesima prima, or first sexagesimal integer, and a single dash, or small stroke, was placed at its top; thus, sixty was expressed 1′. So on again to fifty-nine times sixty, or three thousand five hundred and forty, which was thus expressed LIX′. It then proceeded to sixty times sixty, which was called a sexagesima secunda, or second sexagesimal integer, and expressed thus, 1″. In like manner, twice sixty times sixty, or seven thousand two hundred was expressed by 11″, and so on, to sixty times three thousand six hundred, which was a third sexagesimal, and thus expressed 1‴.

The notation, now in use, and which is by far the most convenient, was transmitted into Europe from the Arabians or Saracens, who did not, however, pretend to be the inventors of those characters, and that method, but confessed that they received them from the Indians. The first elements of arithmetic are acquired in infancy. The idea of one, of any kind of objects, is the most simple. By placing one object near to another, the idea of two is gained; and by continually adding one to the former collection, the ideas of three, four, and every higher number, is communicated. As we thus advance from lower numbers to higher, we shall soon find that

there is no limit to this increasing operation; and that whatever number of objects be collected together, more may be still added; so that we can never reach the highest possible number, nor approach near to it. As by collecting objects, we are led to understand and add numbers, so by removing the objects collected, we learn to diminish numbers. It is very difficult to form any adequate conception of very high numbers. We frequently speak of numbers, of the extent of which we have no adequate idea. If a person were to reckon a hundred balls every minute, and were to continue at work so reckoning, ten hours a day, he would spend seventeen days in reckoning one million; and a thousand men, reckoning at the same rate, would take forty five years, to number out a billion.

All numbers are represented by the ten following characters.

1. 2. 3. 4. 5. 6. 7. 8. 9.
one, two, three, four, five, six, seven, eight, nine,
0. cypher, or nought.

The nine first are called significant figures or digits, and accordingly, as they are placed, represent units, tens, hundreds, or higher classes of numbers. When placed singly, they denote the simple numbers signified by the characters. When several are placed together, the first, or right hand figure only, is to be taken for its simple value; the second, signifies so many tens; the third, so many hundreds; and the others, so many higher classes, according to the order in which they stand. And as it may sometimes be requisite to express a number consisting of tens, hundreds, or higher classes, without any units or

[illegible]

constitute the foundation of all arithmetical ... How is the idea of fractions obtained? Wh... fractions? And what are decimal fractions? ... are adopted for the sake of abbreviation.

CHAP. XI.

ARITHMETIC — continued.

ADDITION teaches how to find the a... any given numbers.

Rule. — According to the principle... numeration, place the figure... added under each other, according to ... units under units, tens under te... hundreds under hundreds, and so on. ... together the units; set down ... figure of their sum, and carry on the te... next column; continue the operation ... column, under which ... its whole amount.

Example 1. Add together the follo... numbers, 9414, 394, 29, 7451, and ... The numbers being thus pr... arrangement of units under units, t... tens, hundreds under hundreds, thousa... thousands, and tens of thousands und... thousands, they are added together,

Characters, expressing	
$=$ Equal to.	The sign of equality.
$+$ Plus, or more.	The sign of addition, as, $9+9=18$, that is, nine added to nine, are equal to eighteen.
$-$ Minus, or less.	Sign of subtraction, as, $9-5=4$, nine less five equal to four.
$\times$ Multiplied by.	Sign of Multiplication, as $8\times8=64$, eight, multiplied by eight, equal to sixty-four.
$\div$ Divided by.	Sign of division, as $28\div7=4$, twenty-eight, divided by seven, equal to four.
$:\ ::\ :$ Proportion.	Sign of Proportion, as, $8:16::16:32$, eight is to sixteen, as sixteen to thirty-two.

QUESTIONS.

What is the science of arithmetic, and what is its apparent antiquity? How did the Greeks represent their numbers? What are the Roman characters for numbers? What is sexagesimal arithmetic; when, and by whom was it invented? Whence came the characters and mode of notation of numbers now in use? How are the ideas of addition gained? Is it easy to acquire a distinct idea of very high numbers? How many characters are employed to represent all numbers? Which are the significant figures? How is notation or numeration, performed? What rules

constitute the foundation of all arithmetical operations? How is the idea of fractions obtained? What are vulgar fractions? And what are decimal fractions? What signs are adopted for the sake of abbreviation.

CHAP. XI.

ARITHMETIC — continued.

ADDITION teaches how to find the amount of any given numbers.

Rule. — According to the principle of notation, or numeration, place the figures to be added under each other, according to their value; units under units, tens under tens, hundreds under hundreds, and so on. Begin by adding together the units; set down the unit figure of their sum, and carry on the tens to the next column; continue the operation till you come to the last column, under which put down its whole amount.

Example 1. Add together the following sets of numbers, 94141, 394, 29, 7451, and 35120.

The sets of numbers being thus prepared by the arrangement of units under units, tens under tens, hundreds under hundreds, thousands under thousands, and tens of thousands under tens of thousands, they are added together, as follows.

94,141
394
29
7,451
35,120
137,135

Fifteen is the amount of the column of units; the five, therefore, is placed under that column, and the one, that is one ten, is carried to the second column, being that of tens. The amount of the second column, with the one which was brought to it from the first column, is twenty-three; that is, twenty-three tens; the three is, therefore, placed under the column of tens, and the two is carried on to the column of hundreds. The next column is then added up, which, with the two brought to it from the preceding column, amounts to eleven, that is, eleven hundreds; one is, therefore, placed under the columnofhundreds, and one, is carried forwards to the next column, which, with it, amounts to seventeen: that is, seventeen thousands; the seven is placed under the column of thousands, and the *one* carried forwards to the next and last column, that of tens of thousands, and being added together with that, makes the sum of thirteen, which, as there is no other column, is written down in full.

Example 2.

```
 789
 453
 641
 894
————
2777
————
```

In this example, seventeen is the sum of the units, the seven is placed under the unit column, and one, that is one ten, is carried to the second column. The second column, with the figure brought from the unit column, is then added up; it amounts to twenty-seven; that is, twenty-seven tens; the seven is, therefore, placed under the column of tens, and the two is carried on to the column of hundreds. The next column is then added together, with the two, brought on, amounting to twenty-seven, which is written down as a whole. The sum then of the figures to be added together is 2777.

COMPOUND ADDITION.

When the given numbers consist of articles of different value, as pounds, shillings, pence, grains, ounces, pints, quarts, &c. which are called different denominations, the operation of adding together such sets of numbers must be regulated by the value of the articles. Such addition is styled, compound addition.

TABLES.

STERLING MONEY.

4 Farthings	=	1	Penny.
12 Pence	=	1	Shilling.
20 Shillings	=	1	Pound.
6s. 8d.	=	1	Noble.
12s.	=	1	Angel.
13s. 4d.	=	1	Mark.

AVOIRDUPOIS WEIGHT.

16 Drams	=	1	Ounce, oz.
16 Ounces	=	1	Pound, lb.
28 Pounds	=	1	Quarter, qr.
4 Quarters	=	1	Hundred weight, C.
20 Hundred weight	=	1	Ton, T.

TROY WEIGHT.

20 Mites	=	1	Grain, gr.
24 Grains	=	1	Penny-weight, dwt.
20 Penny-weights	=	1	Ounce, oz.
12 Ounces	=	1	Pound, lib.

APOTHECARIES' WEIGHT.

20 Grains	=	1	Scruple, ℈.
3 Scruples	=	1	Dram, ʒ.
8 Drams	=	1	Ounce, ℥.
12 Ounces	=	1	Pound, ℔.

DRY MEASURE.

2 Pints	=	1	Quart.
4 Quarts	=	1	Gallon.
2 Gallons	=	1	Peck.
4 Pecks	=	1	Bushel.
8 Bushels	=	1	Quarter.

WINE MEASURE.

4 Gills		1	Pint.
2 Pints	=	1	Quart.
4 Quarts	=	1	Gallon.
63 Gallons	=	1	Hogshead.
84 Gallons	=	1	Puncheon.
2 Hogsheads	=	1	Pipe.
2 Pipes	=	1	Tun.

ALE AND BEER MEASURE.

2 Pints	=	1	Quart.
4 Quarts	=	1	Gallon.
9 Gallons	=	1	Firkin.
2 Firkins	=	1	Kilderkin.
2 Kilderkins	=	1	Barrel.
54 Gallons	=	1	Hogshead.
2 Hogsheads	=	1	Butt.

LAND MEASURE.

30¼ Square yards	=	1	Pole or perch.
40 Poles	=	1	Rood.
4 Roods	=	1	Acre.

LONG MEASURE.

12 Inches	=	1	Foot.
3 Feet	=	1	Yard.
5½ Yards	=	1	Pole.
40 Poles	=	1	Furlong.
8 Furlongs	=	1	Mile.
3 Miles	=	1	League.

TIME.

60 Seconds	=	1	Minute.
60 Minutes	=	1	Hour.
24 Hours	=	1	Day.
7 Days	=	1	Week.
365 Days	=	1	Year.
52 Weeks & 1 day	=	1	Year.

Rule. — Arrange the numbers of the same denomination under one another. Add up the figures of the lowest denomination, and if their sum do not amount to one unit of the next denomination, set it down under the column just added; but if the sum amount to one unit, or more, of the next denomination, set down only the excess of the sum above the units, and carry the units to the column of the next higher denomination; which add in the same way as before. Continue this operation through all the denominations, to the highest; the sum of which, together with the several remainders before set down, will be the answer.

Example. —

£.	s.	d.
42	13	$5\frac{1}{4}$
35	16	$3\frac{1}{2}$
13	11	7
59	18	$11\frac{3}{4}$
61	10	$5\frac{1}{2}$
27	17	$8\frac{3}{4}$
£241	8	$5\frac{3}{4}$

In this example, the farthings being of the lowest denomination, are first added. Their amount is eleven farthings, equal to two-pence and three farthings; the three farthings are set down under the column of farthings, and the two-pence are carried on to the column of pence, the amount of which is forty-one pence, equal to three shillings and five pence. The five is placed under the column of pence, and the three carried on to the column of shillings, which amounts to

eighty-eight, equal to four pounds, eight shillings. The eight is set down under the column of shillings, and the four is carried on to the column of pounds, the figures of which are added and placed as in simple addition.

The surest proof of the justness of any operation of addition, is to begin at the top of each column, and add downwards. If the amount be the same, it may be concluded that the operation is just.

Subtraction teaches how to find the difference between any two numbers by taking the less from the greater.

Rule.—Place the less number under the greater, in the same manner as addition; begin at the unit column, and continuing from the right to the left, subtract each figure from that which stands over it, setting down the remainder under, and a cypher when nothing remains. Thus,

From	9876543
Take	7765432
Remainder	2111111

But if any figure in the lower line be greater than the figure above it, add ten to the upper figure; from their amount, subtract the lower figure, carry one to the next under figure, and continue as before; thus,

From	87123172
Take	18234433
Remainder	68888739

For a proof, add the remainder to the lower line of figures, and if the amount be the same as the upper line, the operation is right; as,

18234433
68888739

87123172

In the former of the preceding examples, begin with the unit figure, three; and as that cannot be subtracted from two, the figure above it, borrow one ten from the seven tens which stand next the two, and add that one ten to the two, which makes it twelve; then subtract the three from that compounded number twelve, and there remains nine. Set down the nine under the three, and proceed. But as one ten has been borrowed from the tens, there will remain but six tens instead of seven, from which six, when three, the under figure is subtracted, there will remain three, which set down below; and go on as before. Or, when one ten is thus borrowed, it may be added to the lower figure, instead of being subtracted from the upper.

Rule for Compound Subtraction. — As in simple subtraction, place the smaller under the greater numbers, and subtract each number in the lower line from the corresponding figure in the upper, and set down the remainders. When any one of the lower numbers is greater than the number above it, add to the upper number, as many as make one of the next superior denomination; from which com-

bined numbers subtract the figure in the lower line, set down the difference, and carry one to the next number in the lower line; which subtract as before. Example.

£	s.	d.
761	18	$3\frac{1}{2}$
92	7	$10\frac{3}{4}$
£669	10	$4\frac{3}{4}$

Multiplication is the method of finding the amount of any given number, repeated a given number of times. It is a kind of addition, but much more expeditious than the common mode of addition. The number to be multiplied or repeated, is called the multiplicand, the multiplying number is called the multiplier, and the result of the operation is called the product. Both the multiplier and multiplicand are termed factors.

Rule. — When the multiplier does not exceed twelve, begin at the units' place of the multiplicand; and if the product do not exceed nine, set it down under the multiplier; but if it be ten, or more, set down only the units, and carry the tens to be added to the next product, and let the last product be set down entire.

Proof. — Write down the figures of the multiplicand as many times as they are contained in the multiplier, and add them together.

Example —		9472
Multiply	9472 by 9	9472
	9	9472
		9472
	85248	9472
		9472
		9472
		9472
		9472
		85248

When the multiplier consists of several figures, multiply the multiplicand successively, by each figure in the multiplier, placing the first figure of each product exactly under that figure of the multiplier, by which you are multiplying. Then add the columns of products.

Example —

Multiplicand	27831
Multiplier	243
	83493
	111324
	55662
Product	6762933

Proof. — Multiply the multiplier by the multiplicand.

Rule for multiplying given numbers of different denominations; or compound multiplication. Multiply the number of the lowest denomination by the multiplier. If the product be less

than will make one of the next higher denomination, set it down; but if greater, find how many of the next higher denomination it contains; carry them as in addition, and write down only the remainder.

If the multiplier exceed twelve, multiply by its component parts successively; but if the multiplier cannot be exactly produced by the multiplication of simple numbers, take the nearest number to it, either greater or less, and multiply by its parts as before. Then multiply the given multiplicand by the difference between the assumed number and the multiplier, and add the product to that before found, when the assumed number is less than the multiplier; but subtract the same when it is greater.

Examples.

Multiply £23 16 7½ by 6.
6
£142 19 9

Multiply £30 7 6½ by 37
6
182 5 3
6
1093 11 6
30 7 6
1123 19 0

6 × 6 = 36 + 1 = 37

Multiply £42 7 9 by 21
3
£127 3 3
7
£890 2 9

3 × 7 = 21

Division teaches in what manner to find how often one number is contained in another number, and is a short method of performing sub-

traction. The number to be divided is called the dividend; the dividing number is called the divisor; and the number of times the divisor is contained in the dividend, is named the quotient; while what is left after the division is termed the remainder.

Rule.—When the divisor does not exceed twelve, place it on the left of the dividend, and separate them by a line. Find how often the divisor is contained in as many figures of the dividend as may be necessary for that purpose, and set down the quotient under; if there be a remainder, consider it as tens; place it before the next figure of the dividend, and divide by the divisor. Continue this operation to the end of the sum, and if there be any remainder, set it down on a line with the quotient, but separated from it by a mark. Examples.

Divide 3429 by five.

	Divisor.	Dividend.
	5)	3429
Quotient		685 : 4 Remainder.

Divide 7834 by twelve.

	Divisor.	Dividend.
	12)	7834
Quotient.		652 : 10 Remainder.

When the divisor is a composite number, and one of the component parts also measures the dividend, we may divide successively by the component parts.

Example.—Divide 94152 by 21.

$$3 \times 7 = 21 \qquad \begin{array}{l} 3)\ \underline{94152} \\ 7)\ \underline{31384} \\ \quad 4483 \cdot 3\ \tfrac{3}{21} \end{array}$$

When the divisor exceeds twelve, and consists of several figures, place the divisor before the dividend, as before, and find how often the divisor is contained in as many figures of the dividend as are necessary; place that number on the right of the dividend; multiply the divisor by that number, and set the product under the figures of the dividend, just divided; subtract this product from those figures of the dividend under which it stands; and bring down the next figure of the dividend, or more if necessary, to join on the right of the remainder. Divide the number so increased, as before; and continue the same operation until all the figures be brought down.

If it be necessary to bring down more figures than one to make the remainder as large as, or larger than, the divisor, place a cypher in the quotient for every figure so brought down more than one figure.

Example.—Divide 16524 by 54.

$$\begin{array}{r} 54)\ 16524\ (306 \\ \underline{162} \\ 324 \\ \underline{324} \\ \cdots \end{array}$$

If there be cyphers on the right hand of the divisor, cut off those cyphers from the divisor, and an equal number of figures from the right hand of the dividend; then divide the remaining figures of the dividend, by the remaining figures of the divisor, and place the figures cut off from the dividend, on a line with the remainder, if there be any.

Example.—Divide 630,27 by 500.

5,00) 630,27

Quotient 126,27 Remainder.

COMPOUND DIVISION.

Rule.—When the dividend consists of different denominations, divide the higher denomination, and reduce the remainder into the next lower denomination, taking in the given number of that denomination, and then continue the division. Examples.

```
   £.  s.  d.
5) 77  10  9½
   ----------
   15  10  1⅞
   ----------

      £.   s.  d.   £.  s. d.
32)  550  18  10  (17  4  4
     32
     ---
     230
     224
     ---
       6
      20
     ---
     138
     128
     ---
      10
      12
     ---
     130
     128
     ---
       2
```

QUESTIONS.

What is addition, and what is its rule? What is the rule for compound addition? What is the surest proof of addition? What is subtraction, and its rule of operation? What is the proof? What is the rule for compound subtraction? What is multiplication, its rule, its proof? What is the rule for compound multiplication? What is division, and its rule? What is the rule for compound division?

CHAP. XII.

ARITHMETIC — continued.

DECIMAL FRACTIONS.

THE formation and calculation of decimal fractions are founded upon the same principles, as is the numeration of integers. When a unit is divided into decimals, that unit is supposed to consist of ten parts, in the same manner as one ten in the arithmetic of integers, is worth ten units. The decimal parts of units, therefore, are tenths, and are placed at the right hand of the units, with a dot between them, to determine their place. Thus, thirty-five units and six tenths, are expressed as follows, 35.6. The first figure of a decimal fraction signifies tenth parts; the next hundredth parts, the next thousandth parts, and so on.

The use of cyphers in decimals, as well as in integers, is to bring the significant figures to

their proper places, on which their value depends. As cyphers, when placed on the left hand of an integer, have no sigification; but when placed on the right hand, increase the value, each, ten times; so cyphers when placed on the right hand of a decimal have no effect; but when placed on the left, diminish the value ten times each.

Examples of notation and numeration of decimals.

4.7	signifies	four integers, and seven tenth parts.
0.47	———	four tenth parts and seven hundredth parts, or forty-seven hundredth parts.
0.047	———	four hundredth parts, and seven thousandth parts, or forty-seven thousandth parts.
0.407	———	four tenth parts, and seven, thousandth parts, or 407 thousandth parts.
4.07	———	four integers and seven hundredth parts.
4.007	———	four integers and seven thousandth parts.

Addition of decimals.—Rule. Place the numbers under each other according to their value, as in integers, so that all the decimal separating dots may stand exactly under each other. Then begin at the right hand; add up all the columns and place the dot in the amount, exactly below all the other dots.

Example. 51.9205
3412.
21.02
0.8654

3485.8059

Subtraction of decimals.—Arrange the numbers under each other, as before, according to their value; then begin at the right hand; subtract as in whole numbers, and point off the decimals, as in addition.

Example. From 65.378 take 6.45
65.378
6.45

58.928

When the number of decimals is less in the superior, than in the inferior number, add as many cyphers to the superior number, as will make the number of decimals equal; for, as before observed, the value of decimals is not altered, by placing any number of cyphers after the last figure.

Example. From 22.6000
Take 4.7325

17.8675

Multiplication of decimals.—Rule. Place the factors, and multiply them as in the multiplication of integers. Then mark off just as many

decimals in the product, as there are decimals in both factors; and if there should not be a sufficient number of figures in the quotient, supply the defect by prefixing cyphers.

Example. Multiply 46.25 by 34

```
   46.25
      34
  ------
   18500
  13875
  ------
 1572.50
```

When one, or both of the factors consists solely of decimals, the operation is founded on the same principle as the preceding.

Example. Multiply 4.31 by 0.5

```
  4.31
     5
 -----
 2.155
```

Division of decimals.—Rule. Divide as in whole numbers; but if the divisor, or dividend, or each of them, have decimals, add to that which has none, or to that which has less than the other cyphers, until the number of decimals in both be equal.

Example. Divide 81.54 by 27

```
2700) 8154 (3.02
      8100
      ----
        5400
        5400
```

VULGAR FRACTIONS.

A vulgar fraction is expressed by two numbers placed one over the other, and separated by a line, thus $\frac{3}{5}$, $\frac{4}{5}$, $\frac{1}{4}$.

The number under the line is called the denominator, and shows into how many equal parts the whole quantity is divided.

The number above the line is called the numerator and shows how many of those parts are expressed by the fraction.

Example. 1 yard and $\frac{2}{3}$. Here the denominator 3 shows that the whole yard is divided into three parts; and the numerator 2, shows that the fraction contains two of those parts.

Fractions are divided into proper, improper, simple, and compound, or mixed.

A proper fraction is when the numerator is less than the denominator; as $\frac{1}{4}$, $\frac{2}{3}$, $\frac{3}{8}$.

An improper fraction is when the numerator is equal to, or greater than, the denominator; as $\frac{4}{4}$, $\frac{3}{2}$, $\frac{6}{3}$.

A simple fraction denotes any number of parts of the whole number, as $\frac{2}{3}$, $\frac{3}{7}$.

A compound fraction is the fraction of a fraction, as $\frac{1}{2}$ of $\frac{3}{5}$, of $\frac{6}{7}$ of $\frac{7}{8}$.

A mixed or compound fraction consists of a whole number, and a fraction, as $5\frac{2}{3}$, $8\frac{5}{8}$.

Reduction of vulgar fractions, is, the changing them from one denomination to another, to prepare them for the operations of addition, subtraction, multiplication, and division.

To reduce fractions to their lowest terms.

Rule.—Divide the terms of the given fraction by any number that will divide them both without a remainder; then continue dividing the quotients in the same manner, until there is no number greater than one, which will divide them, and the fraction will then be in its lowest term.

Example. Reduce $\frac{210}{252}$ to the lowest terms.

$$\tfrac{210}{252} \div 6 = \tfrac{35}{42} \div 7 = \tfrac{5}{6}$$

```
210) 252 (1
     210            Proof 42)  210/252 = 5/6.
     ---
      42) 210 (5
          210
          ---
```

The rule for finding the greatest common measure of two numbers is this. Divide the greater by the lesser number; and then divide the divisor by the remainder; and continue dividing the last divisor by the last remainder, until nothing remain; and the last divisor will be the common measure, by which divide both terms of the fraction as above.

To reduce a mixed number to its equivalent improper fraction.

Rule.—Multiply the integer by the denominator of the fraction, and to the product add the numerator. The sum is the numerator of the improper fraction sought, and is placed above the given denominator.—Example.

Reduce $15\frac{3}{8}$ to an improper fraction.

$$15 \times 8 = 120 + 3 = 123 = \tfrac{123}{8}$$

Proof $123 \div 8 = 15\frac{3}{8}$.

Addition of vulgar fractions.—Rule. If the

fractions have a common denominator, add all the numerators together, and place their sum over the common denominator, which will be the amount required. But if the proposed fractions have different denominators, reduce them all to the least common denominator, over which place the numerators as before.

Example. Add together $\frac{3}{4}$ $\frac{2}{3}$ $\frac{2}{5}$ and $4\frac{1}{2}$.

2) 4352 then $2 \times 2 \times 3 \times 5 \times 1 = 60$, which is the least common denominator.

2351

Then $60 \div 4.3.5.2 = 15.20.\ 12.\ 30.$ which, multiplied by all the numerators, give

$\frac{45}{60} + \frac{40}{60} + \frac{24}{60} + \frac{270}{60} = \frac{379}{60} = 6\frac{19}{60}$. Answer.

Subtraction of vulgar fractions.—Rule. Prepare the fractions in the same manner as for addition, if necessary; then subtract the less numerator from the greater, and under the difference, place the common denominator.

Example. From $\frac{3}{5}$ take $\frac{6}{7}$.

$3 \times 7 = 21$

$5 \times 6 = 30$ Then $\frac{30}{35} - \frac{21}{35} = \frac{9}{35}$. Answer.

$5 \times 7 = 35$

Multiplication of fractions.—Rule. Reduce mixed numbers, if there be such, to improper fractions; and compound fractions to simple fractions. Then multiply all the numerators together, for a new numerator; which will give the required product. Example.

Multiply $4\frac{2}{7}$, $\frac{3}{5}$, and $\frac{4}{6}$ of 8, together.

$\frac{30}{7}$, $\frac{1}{5}$, $\frac{16}{3}$, $\frac{6}{7} \times 16 = 13\frac{5}{7}$. Answer.

Division of fractions.—Rule. Prepare the fractions as in multiplication; then divide the numerator by the numerator, and the denominator by the denominator if they will exactly divide; but if not, invert the terms of the divisor, and proceed as in multiplication.

Example. Divide $\frac{16}{9}$ by $\frac{2}{3}$.

$\frac{16}{9}-\frac{2}{3}=\frac{8}{3}=2\frac{2}{3}$. Answer.

QUESTIONS.

What is a fraction? What are decimal fractions? What is the use of cyphers in decimal fractions, and what power have they when placed to the right or left of a decimal? How is the notation of decimals carried on? What is the rule for addition of decimals? What is the rule for subtraction, for multiplication, and for division of decimals? What is a vulgar fraction? What is the numerator, and what is the denominator of a vulgar fraction? How are vulgar fractions divided? What is reduction of vulgar fractions? How are fractions reduced to their lowest terms? What is the rule for finding the greatest common measure of two numbers? How can you reduce a mixed number to its equivalent improper fraction? What is the rule for addition of vulgar fractions? For subtraction of vulgar fractions? For multiplication and division of vulgar fractions?

CHAP. XIII.

ARITHMETIC — continued.

Reduction is the changing of numbers from one denomination to another without altering

their value, and is used chiefly in bringing money, weights and measures, to common denominations.

When numbers are to be reduced from higher to lower denominations, it is called reduction descending. When numbers are to be raised from a lower to a higher denomination, it is called ascending reduction.

All cases of reduction descending are solved by multiplication. All cases of reduction ascending are performed by division.

Examples. — Reduce £14 5 6½ into farthings.

```
£14  5  6½
 20
----
 285
  12
----
3426
   4
-----
13706
-----
```

In 1720 farthings how many pounds?

```
   4) 1720
      ----
  12)  430
      ---------
 2,0)  3,5 10
      ---------
      £1 15 10
      ---------
```

PROPORTION. — Four quantities are said to form a proportion, when there is the same ratio, or relation between the first and second, as there is between the third and fourth of them.

There are two different kinds of ratios between quantities, namely, arithmetical and geometrical. Arithmetical proportion, is the existence of the same difference between the first and second, and the third and fourth, of four numbers. As 9, 11; 13, 15. This is expressed by placing one dot between the two terms of each ratio, and two dots between the two members of the proportion. Thus, 9. 11 : 13. 15; that is, as nine is to eleven, so is thirteen to fifteen.

Geometrical proportion is, when the first quantity contains, or is contained in, the second; in the same manner as the third contains, or is contained in, the fourth.

Example. — 3, 9 : 4, 12. This proportion is expressed by placing two dots between the two terms of each ratio; and four dots between the two members of the proportion. Thus 3 : 9 : : 4 : 12, that is, the number three is contained in nine, as often as the number four is contained in twelve.

The first and last terms of a proportion are called extremes, from being placed at the extremities, and the terms lying between them are called mean terms.

When four quantities are in geometrical pro-

portion, the product of the two extremes is equal to the product of the two means. The whole theory of geometrical proportion rests upon this property. Since the product of the extremes is equal to the product of the means, it follows that if the two mean terms are multiplied together, and their product divided by the first extreme, the quotient of that division must be the other extreme.

Upon this principle are founded simple multiplication, and the rule of three, direct, inverse, and compound; and indeed every rule where the answer is obtained by establishing a proportion between given quantities. To resolve a question by the rule of proportion, or rule of three, the three given quantities must be so disposed as that the same ratio may exist between the third, and the fourth the one sought for, as between the first and second.

The rule of three teaches, by three given numbers, to find a fourth in the same proportion to the third, as that of the second to the first.

Rule. — Place the numbers so as that the first and third may be of the like kind, and that the second may be of the same as the number required.

Then reduce the first and third terms into the same denomination, and bring the second into the lowest term mentioned.

Multiply the second and third numbers together, and divide the product by the first. The quotient will be the answer, of the same denomination as the second term.

Example. — If 2lb. of sugar cost 19½d. what will 25cwt. cost at the same rate.

```
lb.  d.      cwt.
2 : 19½ :: 25   :  the unknown quantity
      4       4
     --    ----
     78     100
     --      28
           ----
            800
            200
           ----
           2800
             78
          -----
          22400
         19600
         ------
      2) 218400 (in their lowest denomination.
         ------
      4) 109200  Answer in farthings.
         ------
     12)  27300    —    in pence.
         ------
    2,0)  227,5    —    shillings.
         ------
        £113 15  Answer general.
         ------
```

Inverse Proportion is when more requires less, or less requires more.

More requires less, when the third term is greater than the first, and requires the fourth term to be less than the second. Less requires more, when the third term is less than the first,

and requires the fourth term to be greater than the second.

Rule. — State the question, and if necessary, reduce the terms as before. Multiply the first and second terms together, and divide the product by the third; the quotient will bear such proportion to the second, as the first does to the third.

Example. — If a certain quantity of work be executed in 28 days by five men, how many men will do the same in 10 days?

days		men		days	
28	:	5	: :	10	to the unknown
5					number of men.
10) 140					
14 Men; the answer.					

Compound Proportion, or Double Rule of Three, or Rule of Five, is a rule in which more than three terms are given to find another dependent upon them.

Rule. — Place the terms of supposition one above another in the first place. Set down in the middle, the term which is of the same nature with the answer sought. Place the terms of demand one above another in the third place. Multiply the numbers standing under each other on the left hand side of the middle term; and in like manner multiply together all those on the right hand side of it. Then multiply the middle term by the latter product, and divide the result

by the former product; and the quotient will be the answer required.

Example. — If 8 men can reap 40 acres in 7 days, how many acres may be reaped by 23 men in 28 days?

men 8 days 7	Acres 40	men 24 days 28	$24 \times 28 \times 40 = 26880$ $26880 \div 7 \times 8 = 56$ Product 480 acres which is the answer.

Practice, so called from its general use in business, is a short method of working the rule of three direct: that is, whenever the first term of the questions is unity.

All questions in this rule are performed by taking aliquot parts. The aliquot parts of any quantity or number; are such as will exactly divide it without remainder. Thus three and six are aliquot parts of eighteen, six-pence is an aliquot part of a shilling; and four shillings is an aliquot part of a pound.

Example. — Bought 3428 lbs. of beef at 8½d per lb. what is the amount?

6d	$\frac{1}{2}$	3428	at 8½
2	$\frac{3}{4}$	1714	
$\frac{1}{2}$	$\frac{1}{4}$	571	4
		142	10
	20	242,8	2
		121 8	2 Answer.

Tare and Tret are a set of practical rules which teach how to deduct certain allowances

made by wholesale dealers, on selling their goods by weight.

INTEREST is the sum of money paid or allowed for the loan of some other sum lent for a certain time, according to some fixed rate.

The sum lent is called the principal.

The sum which is paid for every hundred pound lent, by the year, is called the rate.

The principal and rate added together is called the amount.

Simple interest is that which is reckoned on the principal only, during the whole time it is lent.

Compound interest, is that which is reckoned not only on the principal, but also upon the interest, which may remain unpaid; and which consequently must be continually augmenting, until payment of the amount be made.

All the operations of calculating interest are carried on by rules of proportion, in which three quantities are given to find a fourth. The usual proportion is, as £100 is to the sum proposed, so is the interest, or value, of £100 to the required interest or value of the proposed sum.

COMMISSION or brokerage, is an allowance of a certain sum, upon every hundred pounds, to an agent for buying and selling goods; or to a banker for drawing bills.

BUYING AND SELLING STOCKS.

Stock is a general name for the capital of any

trading company. It signifies, also, any sum of money lent to government, on condition of receiving a certain interest, till the money shall be repaid.

The price of stocks, or the rates per cent, are the several sums for which £100, of the respective stocks sell at any time.

INSURANCE is the obtaining a security for goods or possessions of any kind, in consideration of paying a premium of so much per cent. The insurers engage to answer for damage or loss by fires, casualties at sea, or other accidents.

DISCOUNT is an interest allowed by the debtor to the creditor, when a bill or draft is given instead of ready money, or when long credit is granted.

Rebate signifies a reduction made by the creditor to the debtor, when a payment is made before the time when it becomes due, or when a bill or draft payable at a future date is exchanged for ready money.

PROFIT AND LOSS. — This rule teaches to ascertain how much is gained or lost, on the prime cost in the purchase and sale of goods; it shows also how to fix the price of goods so as to gain a certain sum per cent.

FELLOWSHIP, is a rule, by which any sum or quantity may be divided into any number of parts, which shall be in a given proportion to one another. This is a very useful rule; as by it, the gains or losses of partnerships; the ef-

fects of bankrupts; or legacies, in case of a deficiency, in the assets; or the shares of prizes, are arranged and settled.

ALLIGATION teaches how to mix together simples of different natures, so that the composition may be of some intermediate quality or rate.

EXCHANGE is the receiving of money in one country for the same value paid in another.

POSITION is a method of working certain questions which cannot be resolved by the common direct rules. It is sometimes called the rule of false, because it makes a supposition of false numbers to work with, as if they were the true numbers, and, by this means, discovers the true numbers sought.

INVOLUTION is the raising of powers from any given number as a root.

A power is a number produced by multiplying any given number, called the root, a certain number of times continually by itself. Thus,

$2 = 2$ is the root or first power of 2
$2\times2 = 4$ is the second power or sq. of 2
$2\times2\times2 = 8$ is the third power or cube of 2
$2\times2\times2\times2 = 16$ is the fourth power of 2, &c.

The number denoting the power is called the index or exponent; and it is more than the number of multiplications used in producing the same. Thus 1, is the index of the first power; 2, of the second power; 3, of the third power; 4, of the fourth power, and so on. Powers that are to be raised, are usually denoted by placing the index above the root, or first power.

Thus:

3^2	means	the 2nd power of 3.
3^4	—	the 4th power of 3.
360^5	—	the 5th power of 360.
0.45^6	—	the 6th power of 0. 45.

Example. — What is the 3d power of 25? $25 \times 25 \times 25 = 15625$.

EVOLUTION, OR THE EXTRACTION OF THE SQUARE ROOT. —A square number is the product resulting from the multiplication of any number by itself. Thus, 25 is the square of 5. $5 \times 5 = 25$. When a number is squared, it is made at the same time multiplier and multiplicand. It is thus twice factor of the product, for which reason, this product or square is denominated the second power, of that number. When a square number consists only of one, or two figures, its root in whole numbers is either,

	1	2	3	4	5	6	7	8	9
whose squares are	1	4	9	16	25	36	49	64	81

If the number be not exactly one of these squares, there will be a fraction in the root. The square roots of numbers which are not exact squares, are called surd, or irrational numbers.

EXTRACTION OF THE CUBE ROOT. — A cube number is formed by multiplying a number by itself, and then multiplying again, by that same number, the product of the first multiplication.

A cube is, therefore, the product of a square, multiplied again by the root, from which it originated. Thus 64 is the cube of 4; that is, $4 \times 4 = 16$ the square, multiplied again by 4,

$16 \times 4 = 64$. To extract the cube root, is, therefore, to find out by particular rules and operations, the cube root of any number.

PROGRESSION.— Arithmetical Progression is a series of terms, in which each term exceeds, by the same quantity, the term by which it is immediately preceded or followed, as

2, 4, 6, 8, 10 &c. or 10, 8, 6, 4, 2, &c.

Geometrical Progression is a series of terms, each of which contains the same number of times, that term, by which it is immediately preceded, or is contained in it, the same number of times.

In the first case, the progression is increasing, as, 2, 4, 8, 16, 32, 64, &c.

In the second case, it is decreasing, as 162, 54, 18, 6, 2, &c.

The number, by which the series is continually increased or diminished, is called the ratio.

PERMUTATION AND COMBINATION. — Permutation of quantities is the changing or varying their order.

The combination of quantities, is the showing how often a less number of things can be taken out of a greater number and combined together, with regard to their places, or the order in which they stand.

DUODECIMALS, or cross multiplication, is a rule used by workmen and artificers, for computing the contents of their work.

Dimensions are usually taken in feet, inches and quarters, any parts smaller than these being neglected, as of no consequence. This takes place both in multiplying them together, or in casting up their contents.

QUESTIONS.

What is reduction? What is arithmetical proportion? What is geometrical progression? What is the rule of three direct; Inverse; Double, or rule of five? What is practice? What is tare and tret? What is interest? What is commission or brokerage; and buying and selling stocks? What is insurance? What are discount and rebate? What are profit and loss, and fellowship? Alligation? Exchange? Commission? Position and the rule of false? What is involution? A power? An index? What is evolution, or the extraction of the square root? What is the extraction of the cube root? What is progression? What are permutation and commutation? What is the rule of duodecimals, or cross multiplication.

CHAP. XIV.

FLUXIONS AND LOGARITHMS.

Fluxions, or the method of fluxions, or as it is called on the continent the Differential and Integral Calculi, is a branch of mathematical analysis. It was invented near the end of the seventeenth century, and Sir Isaac Newton and Mr. Leibnitz, two of the most illustrious philosophers of that age, both claimed the discovery.

In the application of Algebra to the theory of curve lines, some of the quantities which are the subjects of consideration, may be conceived of, as having always the same magnitude; such

as the parameter of parabola, and the axes of an ellipse or hyperbola; while others are indefinite as to their magnitudes, and may have any number of particular values; such are the co-ordinates at any point in a curved line. This difference in the nature of the quantities which are compared together has equally place in various other theories, both in pure and mixed mathematics.

This naturally suggests the division of all quantities into two kinds, namely such as are constant, and such as are variable. A constant quantity is that which retains always the same magnitude, however other quantities with which it is connected may be supposed to change.

A variable quantity is that which is indefinite in respect of magnitude, or which may be supposed to change its value.

Thus in the arithmetic of sines, the radius is a constant quantity, while the co-sine, sine, tangent, of an arch, as also the arch itself, are variable quantities. Constant quantities are usually denoted by the first letters of the alphabet, and variable quantities by the last.

Any expression of calculation, containing a variable quantity, together with other constant quantities, is called a function of that variable quantity.

If a variable quantity be supposed to change its value, then a corresponding change will take place in the value of any function of that quantity.

LOGARITHMS.

An admirable contrivance for shortening cal-

culations, was invented by John Napier, a Scotch philosopher. It consists in a set of numbers called Logarithms, or indices of numbers, which were so adapted to the numbers, to be multiplied or divided, that these being arranged in the form of a table, each opposite to a number termed its logarithm, the product of any two numbers in the table was found by the addition of their logarithms; and the quotient arising from the division of one number by another, was found by the subtraction of the logarithm of the divisor from that of the dividend.

Similar simplifications were introduced into the more laborious operations of involution and evolution.

Let two series of numbers be formed, the one constituting a geometrical progression, the other an arithmetical progression. Let the first term of the geometrical progression be unity, or, 1, and that of the arithmetical progression be 0. Thus:

Geom. Pro.	Arith. Pro.
1	0
2	1
4	2
8	3
16	4
32	5
64	6
128	7
256	8
512	9
1024	10
2048	11
4096	12
&c.	&c.

The two series being thus arranged, the terms in the arithmetical series, are called the logarithms of the corresponding terms in the geometrical series; that is, 0 is the logarithm of 1, 2 of 4, 3 of 8, and so on. Hence it appears that the logarithms of the terms of the geometrical series have the two following properties.

1. The sum of the logarithms of any two numbers or terms in the geometrical series is equal to the logarithm of that number or term, of the series which is equal to their product.

Example. — Let the terms of the geometrical series be 4 and 32, then, the terms of the arithmetical series corresponding to them (that is, their logarithms) are 2 and 5. Now, the product of the numbers in the geometrical series is 128, and the sum of their logarithms is 7; and is appears by the table that the logarithm of the former, 128, is 7, the latter number. In like manner, if the numbers or terms of the geometrical series be 16 and 64, the logarithms of which are 4 and 6, we find from the table, that $10=4+6$, is the logarithm of 16×64; that is, 1024.

2. The difference of the logarithms of any two numbers or terms of the geometrical series, is equal to the logarithm of that term of the series which is equal to the quotient arising from the division of the one number by the other.

Example. — Take the terms 128 and 32, the the logarithms of which are 7 and 5. The greater of those numbers, 128, divided by the

less, 32, is equal to 4; and the difference of their logarithms is 2. By inspecting the two series, this last number, 2, is found to be the logarithm of the former, 4. In like manner, if the terms of the geometrical series be 1024 and 16, the logarithms of which are 10 and 4, we find that $1024 \div 16 = 64$; and that $10 - 4 = 6$. But it appears, from the table, that the latter number, 6, is the logarithm of the former, 64.

By these two properties of logarithms, may be found, with facility, the product or the quotient of any two terms of a geometrical series, to which there is adapted an arithmetical series; so that each number has its logarithm opposite to it, as in the preceding short table. For, it is evident, that to multiply two numbers, it is necessary only to add their logarithms; and opposite to that logarithm, which is their sum, the required product will be found.

Example. — Multiply 16 by 128. To the logarithm of 16, which is 4, add the logarithm of 128, which is 7, the sum of those two logarithms, namely 11, the table shows to be the logarithm of 2048; which is the product of 16 multiplied by 128, the product required.

To divide any number in the table by any other number, the logarithm of the divisor must be subtracted from the logarithm of the dividend; the remainder being found among the logarithms, opposite to it will appear the quotient sought.

Example. — Divide 2,048 by 128. From the logarithm of 2048, that is 11, subtract the lo-

garithm of 128, which is 7; opposite to the remainder, 4, stands 16, which is the quotient sought.

In order to form the logarithms of the intervening numbers to those of the table above, a great number of geometrical and arithmetical means were conceived to be interposed between each two adjoining terms of the geometrical and arithmetical series; then, like as the terms of the arithmetical series, are the logarithms of the corresponding terms of the geometrical series, the interpolated terms of the former will also be the logarithms of the corresponding interpolated terms of the latter.

Upon these principles, tables are formed which, exhibiting the logarithms of all numbers within certain limits, may be applied to simplify calculations.

QUESTIONS.

What are fluxions? Who claimed the invention of fluxions? What is a constant quantity? What is a variable quantity? What are logarithms? By whom invented? What is the first property of the logarithms of the terms of the geometrical series? What is their second property? How are these properties applied to the multiplication of two numbers? How are they applied to the division of numbers? What are the examples given?

CHAP. XV.

ALGEBRA.

Algebra is a general method of reasoning concerning the relations which magnitudes of

every kind bear to each other, in respect of quantity. Or, algebra is a method of computation by symbols, which have been invented for expressing the quantities that are the objects of this science; and also, their mutual relation and dependance. It is sometimes called universal arithmetic; because its first principles and operations are similar to those of common arithmetic. The symbols which it employs to denote magnitudes are, however, more general and more extensive in their application than those employed in common arithmetic. Hence, and from the great facility with which the various relations of magnitudes to one another may be expressed by means of a few signs or characters, the application of algebra to the resolution of problems is more extensive than that of simple arithmetic.

Algebra represents quantities of all kinds, by the letters of the alphabet; and the operations to be performed with them are denoted by certain characters, instead of being expressed by words at length.

The term algebra is derived from the Arabians, who assert that the science was invented by Mahomet Ben Musa, who flourished about the ninth or tenth century. But algebra seems not to have been entirely unknown to the ancient mathematicians.

Algebra is either numeral, or literal.

Algebra numeral, or vulgar, is that which is chiefly concerned in the resolution of arithmetical questions. In this, the quantity sought is represented by some letter or character; but all the given quantitities are expressed by numbers.

Algebra literal, or specious, or the new algebra, is that in which all the quantities known, or unknown, are expressed by their species, or letters of the alphabet. Specious algebra is not, like the numeral, confined to certain kinds of problems; but serves, universally, for the investigation or invention of theorems, as well as the solution and demonstration of all kinds of problems, both arithmetical and geometrical.

The letters used in algebra, severally, represent either lines or numbers, as the problem is either arithmetical or geometrical; and, together, they express planes, solids, and powers more or less high, as the letters are in greater or less number. For instance, if there be two letters, a, b, they represent a rectangle, whose two sides are expressed, one by the letter a, and the other by the letter b; so that by their mutual multiplication, they produce the plane $a\ b$. Where the same letter is repeated twice, as, a, a, they denote a square. Three letters, as, a, b, c, represent a solid, whose three dimensions are expressed by the three letters a, b, c; the length by a, the breadth by b, and the depth by c; so that, by their mutual multiplication, they produce the solid, $a\ b\ c$. As the multiplication of dimensions is expressed by the multiplication of letters, and as the number of these may be so great as to become incommodious, the method pursued is, only to write down the root; and, on its right, to insert the index of the power; that is, the number of letters of which the quantity to be expressed consists; as, a^3, a^4, and so on; the

last of which signifies as much as *a* multiplied four times into itself; and so of all the rest.

In algebra, given or known quantities are usually denoted by the leading letters of the alphabet; and unknown quantities, or quantities sought, are denoted usually by the final letters.

These quantities are connected by certain signs or symbols, which serve to shew their mutual relation; while at the same time, they simplify the science, and reduce its operations into smaller compass.

Thus, the sign $+$ plus, or more, denotes Addition.

$\times$ Multiplication.

$-$ minus, or less, Subtraction.

$\div$ denotes Division.

$\sqrt{}$ — expresses the square root of any quantity to which it is prefixed.

$\sqrt{}$ — with a figure over it, is used to express the cube root of any quantity; as $\sqrt[3]{64}$ represents the cube root of 64, that is, 4. In like manner, $\sqrt[4]{16}$ denotes the biquidratic root of 16, or 2.

$=$ denotes Equality.

Quantities which have the sign $+$ prefixed to them are called positive, or affirmative, quantities; and such as are preceded by the sign $-$ are termed negative quantities. When no sign

is prefixed to a qnantity, + is always understood. Quantities which have the same sign, either + or —, are said to have like signs. A quantity consisting of one term, is called a simple quantity; but if it consist of two or more connected terms, it is called compound.

A number prefixed to a letter is called a numerical coefficient, and denotes how often that quantity is to be taken. Thus, $3a$ signifies that a is to be taken three times; when no number is prefixed, the coefficient is supposed to be unity.

The quotient arising from the division of one quantity by another, is expressed by placing the dividend above a line, and the divisor below it. Thus $\frac{12}{3}$ denotes the quotient arising from the division of 12 by 3, and $\frac{b}{a}$ denotes the quotient arising from the division of b by a.

Quantities that have no radical sign ($\surd$) or index annexed to them, are called rational quantities.

The mark :: signifies that the quantities between which it stands, are proportional: thus, $a : b :: c : d$, denotes that a is in the same proportion to b as c is to d.

QUESTIONS.

What is algebra? By what signs or characters does algebra represent quantities of every kind? Whence is the term algebra derived? What is numeral algebra? What is literal algebra? How are known and unknown quantities usually denoted in algebra? What are the signs or marks by which algebra connects quantities? What are positive, and what are negative quantities? What is a coefficient? How is the quotient, arising from the division of one quan-

tity by another, expressed? What are rational quantities? How are the square, and the cube roots of quanties expressed? How is a biquadratic root expressed? What is a simple quantity? What is a compound quantity? When no sign is prefixed to a quantity, what is understood?

CHAP. XVI.

ALGEBRA — continued.

THE fundamental operations in algebra are performed by the four first rules of arithmetic.

Addition, in algebra, is the connecting quantities together by their proper signs, and uniting into term or sum such as are similar. In this rule there are three cases:—

1. When the quantities are like, and the signs like also.

2. When the quantities are like, but their signs unlike.

3. When the quantities are unlike.

In the first case, the coefficients are added together, and the sum set down; to which sum is prefixed the common sign, and the common letter, or letters, subjoined; as,

a	$-\ bn$	$3\ z$
$3\ a$	$-\ 3\ bn$	$2\ z$
$9\ a$	$-\ 5\ bn$	$4\ z$
$5\ a$	$-\ 4\ bn$	z
$12\ a$	$-\ 2\ bn$	$5\ z$
$2\ a$	$-\ 7\ bn$	
		$15\ z$
$32\ a$	$-22\ bn$	

In the second case, subtract the lesser coefficient from the greater, and to the remainder prefix the sign of the greater; then subjoin the common quantity, or letters.

Examples.

$$\begin{array}{rrr} -5a & +8a^3 & +3y \\ +4a & -15a^3 & +4y \\ +6a & -16a^3 & +5y \\ -3a & +3a^3 & +7y \\ +a & +2a^3 & -2y \\ \hline +3a & -18a^3 & +17y \\ \hline \end{array}$$

In the third case, collect all the like quantities as in the preceding cases, and set down those that are unlike, one after another, with their proper signs.

Example.

$$\begin{array}{l} 3\,ny \\ 2\,ax \\ -5\,ny \\ 6\,ax \\ \hline -2\,ny+8\,ax \\ \hline \end{array}$$

SUBTRACTION.

Rule for subtracting quantities.

Change the sign of the quantity to be subtracted into the contrary sign; and, when so changed, add it to the quantity from which it was to be subtracted.

Examples.

$$\begin{array}{r} +9\,a \\ -3\,a \\ \hline +12\,a \end{array} \qquad\qquad \begin{array}{r} +\ 8\,ab \\ +\ 4\,ab \\ \hline +\ 4\,ab \end{array}$$

MULTIPLICATION.

General rule. — If the quantities to be multiplied have like signs, the sign of the product is + ; but if they have unlike signs, the sign of the product is —.

The examples of multiplication may be referred to two cases. 1. When both the quantities are simple. 2. When one, or both of them, is compound.

To Multiply Simple Quantities.

Rule. — Find the sign of the product of the preceding rule, and annex to it the product of the numeral coefficients; then set down all the letters one after another, as in one word.

Examples.

$$\begin{array}{lrrr} \text{Multiply} & +\,a & +\ 8\,y & -\ 5\,ac \\ \text{By} & +\,c & -\ 5\,x & +\ 9\,ab \\ \hline \text{Product} & +\,ac & -40\,xy & -45aabc \end{array}$$

To Multiply Compound Quantities.

Rule. — Multiply every term of the multiplicand by all the terms of the multiplier, one after another, according to the preceding case; and collect their products into one sum, which will be the product required.

Example.

Multiply	$5a - 3y + c$
By	$3a$.
	$15aa - 6ay + 3ac$

DIVISION.

General rule for the signs.—If the signs of the divisor and dividend be like, the sign of the quotient is $+$; but if they be unlike, the sign of the quotient is $-$.

The examples of division admit of three cases.

Case I. When the divisor is simple, and a factor of every term of the dividend.

Rule. — Divide the coefficient of each term of the dividend by the coefficient of the divisor, and expunge out of each term the letter, or letters, in the divisor; the result is the quotient.

Example. — Divide $16abc$ by $4ac$.

From the method of notation, the quotient may be expressed thus, $\frac{16\,abc}{4\,ac}$; but the same quotient is more simply expressed by the rule just given, in this manner, $4\,b$; the fours in 16 being four, and the like quantities ac, ac, being expunged.

Case II. When the divisor is simple, but not a factor of the dividend.

Rule. — The quotient is expressed by a fraction; of which the numerator is the dividend, and the denominator, the divisor. Thus, the

quotient of $3ab^2$, divided by $2mbc$ is the fraction.

$$\frac{3\,ab^2}{2\,mbc}$$

Case III. When the divisor is compound.

Rule 1. — The terms of the dividend are to be arranged according to the powers of some one of its letters; and those of the divisor according to the powers of the same letter.

2. The first term of the dividend is to be divided by the first term of the divisor, observing the general rule for the signs; and this quotient, being set down for a part of the quotient wanted, is to be multiplied by the whole divisor, and the product subtracted from the dividend. If nothing remain, the division is finished; but if there be a remainder, it is to be taken for a new dividend.

3. The first term of the new dividend is next to be divided by the first term of the dividend, as before; and the quotient joined to the part already found, with its proper sign. The whole divisor is also to be multiplied by this part of the quotient, and the product subtracted from the new dividend; and thus the operation is to be carried on, till there be no remainder, or till it appear that there will always be a remainder.

Example.

$$\begin{array}{rl}
2a+3b)\; & 8a^2+2ab-15b^2\;(4a-5b \\
 & 8a^2+12ab \\
\hline
 & \quad -10ab-15b^2 \\
 & \quad -10ab-15b^2 \\
\hline
\end{array}$$

An equation declares the equality of two quantities; and is represented, as has been said before, by the sign $=$; as, 100*s.* $=$ 5*l.*

A simple equation is that which contains only one power of the unknown quantity; thus, $b+c=x$, is a simple equation.

Example 1. — If $x+y=16$, and $x-y=12$, to find the value of x and y.

$$\begin{array}{lcl} x+y & = & 16 \\ x-y & = & 12 \\ \hline 2x & = & 28 \\ x & = & 14 \text{ the half of } 28 \\ y & = & 2 \text{ because } x+y=16. \end{array}$$

Example 2.—What are the two numbers whose sum 65, and difference 9, make x and y the unknown numbers?

$$\begin{array}{lcl} x+y & = & 65 \\ x-y & = & 9 \\ \hline 2x & = & 74 \\ x & = & 37 \text{ the half of } 74 \\ y & = & 28 \\ \hline \end{array}$$

QUESTIONS.

How are the fundamental operations in algebra performed? What is addition in algebra, and how is it performed? The first case, second case, the third case? What is the rule for subtraction in algebra? What is the rule for the multiplication of simple quantities? What is the rule for multiplying compound quantities? What is the general rule for the signs to prepare for division in algebra? What is the first case and its rule? What is

the second case and its rule? What is the third case, and what are its rules? What is a simple equation? The examples?

CHAP. XVII.

GENERAL PHYSICS. — ASTRONOMY.

Astronomy is that science which treats of the heavenly bodies; of their number, forms, motoins, and the laws by which those motions are governed. The term Astronomy, is derived from two Greek words, signifying star and law. It is a sublime and useful science. It may be regarded as the triumph of philosophy and the human mind. It has conferred upon mankind the most valuable benefits, as it certainly has been the grand conductor and friend of navigation.

Astronomy is, without doubt, of very high antiquity; but its early history is too much disfigured by fabulous representations, to afford any firm ground of dependance. The Jewish historian, Josephus, asserts, that before the deluge, Seth and his posterity had made considerable advances in this science, and had engraved its principles upon two pillars, one of which existed in his time. The greater part of authors, however, agree in attributing the origin of astronomy to Egypt, or Chaldea. The Egyptians boasted of their colleges of priests, by whom astronomy was taught; and of the monument of Osyman-

dias, in which, it is asserted, was a golden circle 365 cubits in circumference, and one cubit thick. The upper face was divided into 365 equal parts, answering to the days of the year; and on every division were engraved the name of the day, and the heliacal rising of the several stars for that day; with conjectures, from their rising, concerning the weather. The position of the pyramids, those wonderful structures, seems to confirm the claim of the Egyptians to a very early knowledge of astronomy; for their faces are directed, with great precision, towards the four cardinal points of the compass; which circumstance indicates that they were acquainted with some method of drawing a correct meridional line; which is no easy operation. The Chaldeans had their temple of Belus, which was a very lofty tower, probably answering the purpose of an observatory. From the testimony of ancient writers, it appears that they taught the spherical form of the earth; that they knew the causes of eclipses of the moon; could foretel them as well as the appearance of comets; and that they attempted to measure the magnitude of the earth and the sun. From Chaldea, it seems that this science passed into Phenicia, and thence to Greece; where it was greatly improved by Thales, the Miletian, who travelled into Egypt, and brought back with him the first principles of the science. After him, Pythagoras greatly advanced the knowledge of astronomy; for he taught that the sun is the centre of our system, that the earth is round, that the moon is visible by reflecting the sun's rays, that

comets are wandering stars, and the milky way a vast collection of small stars.

Eudoxus, the Cnidian, made great progress in astronomy, and was acquainted with the method of drawing a sun-dial upon a plane. Archimedes discovered the distances of several of the heavenly bodies from the sun, and from one another. Hipparchus was the first who applied himself to the study of every part of astronomy. His predecessors had considered chiefly the motions and magnitudes of the sun and moon. The Arabians also paid great attention to astronomy; but intermingled with it too much of superstition and imagination. This science was cultivated in Europe, by the successive patronage and efforts of Frederick II. of Germany; of Alphonso, of Castile; of Roger Bacon; of Werner; of Copernicus; of Tycho Brahe; of Kepler; of Galileo, who invented the telescope; of Flamstead, Halley, Bradley, Newton, Herschel, Olbers, Piazzi, and Harding, the discoverers of new planets. By the great improvements made in telescopes and other instruments, and the assiduous and accurate observations of many able men, astronomy has now arrived at a high degree of perfection. The forms, distances, magnitudes, motions of the heavenly orbs, are ascertained; and a variety of other curious circumstances respecting them, are well known. Astronomy divides the heavenly bodies, which are called by the general name of stars, into fixed stars, and planets. The former are those stars which retain always the same relative situation to one another; the latter, those which evidently change their relative situa-

tion, and move round some central body. It supposes that the fixed stars are central bodies, or suns, each regulating the motions of a certain number of planets; and that they are all at such immense distances from us, that the nearest is computed to be distant from the earth 32,000,000,000,000 of miles. On account of their apparently various magnitudes, and different degrees of lustre, the fixed stars have been arranged by astronomers in six classes, or orders. Thus, in proportion to their size and splendour, they are called stars of the first, second, third, fourth, fifth, and sixth magnitude. The ancients divided the starry sphere into particular parcels of stars, according to their nearness to one another; so as to occupy those spaces which the figures of different animals or other objects would occupy, if they were delineated over them. These parcels of stars are called constellations, and those stars that are too scattered to be included in any of these constellations, are named unformed stars. The number of the ancient constellations is forty-eight, which modern astronomy has increased to seventy. A remarkable track of whiteness is perceived in the heavens; which, from that circumstance, is called the galaxy, or milky way. This is composed of a vast number of fixed stars, so near to one another that their rays are blended together. Certain whitish spots, likewise, are discernible in the starry sphere; which, when viewed through telescopes, appear magnified and more luminous, but without any perceptible stars in them. They are called lucid spots.

Other spots also are seen; which, to the unassisted eye, seem like dim stars, but through a telescope, present the appearance of broad illuminated patches: in some of which is one star, and in others more are discerned. These are named Nebulæ, or cloudy stars. The sun, and the planets which move round him, constitute the solar, or mundane system. The number of planets was computed to be six; but the discoveries of modern astronomy have added five more. With respect to their distances from the sun, the planets known to ancient astronomy, were thus arranged: Mercury, Venus, the Earth, Mars, Jupiter, and Saturn; of the five new planets, the Georgium Sidus, or Uranus, is beyond Saturn; the four others, Ceres, Pallas, Juno, and Vesta, are between Mars and Jupiter. They are so small, that Herschel, the indefatigable astronomer, and discoverer of the Georgium Sidus, wishes them to be distinguished from the other planets, and to be named Asteriods.

These are called primary planets; while those smaller bodies which revolve about some of them as they move round the sun, are named secondary planets, or moons. There are, also, other bodies which revolve round our sun; but in very eccentric orbits, departing to an immense distance from him, and approaching very near to him. These have the name of comets. From the light and heat which the sun diffuses, that glorious luminary was naturally supposed to be a body of fire; but Herschel, and some other modern astronomers, imagine that the sun is an opaque globe, surrounded by a very extensive

atmosphere, consisting of elastic fluids, that are more or less lucid and transparent, which afford us light, and give or excite heat. Having attentively examined the sun's disk with his powerful telescopes, Dr. Herschel concluded that the dark spots which had been remarked in the sun are parts of its opaque body, seen through rents in its luminous atmosphere; which atmosphere, he supposes to extend from 1843 to 2765 miles from its surface. By the most exact observations, the diameter of the sun has been found to be 883,000 miles; that is, 200,000 timeslarger than the earth.

Dark spots of various figures and magnitudes are seen upon the sun's face, which appear to move over it from east to west. These spots were entirely unknown before the invention of telescopes; and they have shewn an important fact, namely, that the sun revolves round his own axis in about twenty-five days and a half. By the various attractions of the planets moving round him, the sun has also a small movement round the centre of gravity of the system. A third movement of the sun indicates, that, with his planets, he also revolves round some central body. The spots on the sun were first discovered by two astronomers named Harriot and Fabricius, in the year 1610; and were observed with greater accuracy by Scheiner and Galileo, in the following year.

The zodiacal light is another phenomenon attending the sun. It is a triangular beam of light, less bright than the milky way, and rounded a little at the vertex. This is seen, at certain

seasons of the year, before the rising, and after the setting of the sun. Its base is turned towards the sun, and its axis is inclined to the horizon in the direction of the zodiac. As this light accompanies the sun, it is ascribed to an atmosphere round that glorious luminary; extending beyond the orbit of Mercury, and sometimes even beyond that of Venus. The zodiacal light is supposed to be a section of this atmosphere.

Nearest to the sun of all the other planets, revolves Mercury, in about 87 days, 23 hours. The great brilliance of the light reflected from this planet, the shortness of the period during which observations can be made upon its disk, and its position among the vapours of the horizon, when it is observable, have prevented astronomers from making any very important discoveries respecting Mercury.

According to Herschel, he appears equally luminous in every part of his surface, and to have no dark spots, nor ragged edge; while Schroeter, on the contrary, asserts that he has discovered not only spots, but also mountains, in this planet, one of which is ten miles and three quarters high. The daily rotation of Mercury is found to be performed in twenty-four hours and five minutes. He appears a little after sunset, and again a little before sunrise. He never departs farther from the sun than about 27° 5′, so that he is never longer in setting, after the sun, than an hour and fifty minutes, nor does he ever rise sooner than one hour and fifty minutes before that luminary. Very frequently he approaches so near the sun as to be entirely lost in his rays.

Mercury exhibits the same difference of phases with the moon; being sometimes horned, sometimes gibbous, and sometimes shining almost full. Like the moon, the crescent is always turned towards the sun. The distance of this planet from the sun is computed at thirty-two millions of miles, and his diameter at 2,600 miles. In his course round the sun, he moves at the rate of 95,000 miles every hour. The light and heat which he receives from the sun, are almost seven times as great as the quantity which the earth receives; and, to his inhabitants, the sun must appear nearly seven times as large as he does to us. It is evident that Mercury revolves round the sun in an orbit within that of the earth; because he is never seen opposite to the sun, nor distant above fifty-six times the sun's breadth, from his centre.

The planet nearest to the sun, after Mercury, is Venus, the most beautiful of the stars, known by the name of the morning and evening star; because, when she appears west of the sun, she rises before him in the morning; and when in the east, she shines in the evening, after he is set. She presents to view the same phenomena as Mercury; but her different phases are far more apparent.

Venus is computed to be 59,000,000 miles from the sun; and moving at the rate of 69,000 miles every hour, she revolves round the sun in 224 days, 17 hours, of our time. Her diurnal motion is performed in twenty-three hours and twenty minutes, according to one astronomer, Cassini; but according to the opi-

nion of another, Bianchini, Venus takes twenty-four days, eight hours, for each revolution round her axis. Her diameter is 7,906 miles; and by her diurnal rotation, her equator moves at the rate of forty-three miles every hour. Her orbit includes that of Mercury; but is within that of the earth. Several astronomers imagined that they discovered a moon attending upon Venus; but this was, it seems, an optical deception, and no satellite belonging to this planet has, as yet, been seen. She receives twice as much light and heat from the sun as does the earth. According to the measurement of Schroeter, the mountains in Venus are of a still more astonishing height than that he measured in Mercury. A luminous margin round this planet, gives reason to suppose that it has an atmosphere of considerable extent.

The planet Venus has been considered by most astronomers to be about 220 miles less in diameter than the earth; but from the measurements of Herschel, it appears that her apparent mean diameter is 18''.79, or 8,648 miles; while that of the earth is 17''.2, or 7,912 miles.

Mercury and Venus are called inferior planets, because their orbits are included within that of the earth. They are frequently seen between the earth and the sun; and consequently they must be nearer to that luminary than to the earth. These planets appear, at times, to pass over the sun's disk; and such passages are called transits of Mercury and Venus.

QUESTIONS.

What is astronomy? Is astronomy an ancient science, and what nations of antiquity cultivated it? Who were the most illustrious astronomers of ancient and modern times? How does astronomy divide the heavenly bodies? How far distant from the earth, is the nearest fixed star? What are constellations? What was the ancient, and what is the modern number of the constellations? What is the galaxy or milky way? What are nebulæ? Of what bodies does the mundane, or solar system, consist? What were the planets known to ancient astronomy, and in what order are they situated with regard to the sun? What new planets have modern astronomers discovered, and how are they situated with respect to the sun? What are comets? What opinions are formed concerning the nature of the sun? What appearances does the sun's disk present? What motions has the sun? What is the zodiacal light? In what time does Mercury revolve round the sun, and at what distance? What is the diameter of Mercury? Is Mercury easily observed? At what rate does Mercury move round the sun, and what quantity of light and heat does he receive from that luminary? At what distance is Venus from the sun, and in what time does she revolve round him? Why is Venus called the evening and morning star? What is the diameter of Venus, and what quantity of light and heat does she receive from the sun? What is said concerning the mountains of Mercury and Venus? What peculiar appearances do Mercury and Venus present? What common name is given to Mercury and Venus? Why are the orbits of Mercury and Venus supposed to be included within that of the earth? What are transits of Mercury and Venus?

CHAP. XVIII.

ASTRONOMY — continued.

THE earth is placed next after Mercury and Venus, as to distance, from the sun; round whom

it revolves from tropic to tropic, in 365 days 5 hours, 48 minutes, 57 seconds. Its form is an oblate spheroid; that is, round, but flattened a little at the poles, and swelling out at the equator.

Its spherical figure is shown by its shadow being round, as seen in eclipses of the moon; by navigators having actually sailed round it; by the circumstance of the masts of vessels sailing from land remaining in sight longer than their hulks; and by that of the peaks of mountains, and steeples of towers, being first visible to those who are approaching the shore from sea.

The earth revolves about its axis in 23 hours, 56 minutes, 4 seconds. This is called its diurnal motion; by which all parts of the Earth's surface, are successively turned towards and from, the sun; and consequently, pass successively through light and darkness.

The distance of the earth from the sun is, between 95 and 96 millions of miles; and its diameter is about 8000 miles. It revolves round the sun in 365 days, 5 hours, and 49 minutes; moving at the average rate of 58,000 miles every hour; but this motion of the earth in its orbit is irregular. The movement of the earth round its own axis from west to east, occasions the apparent diurnal motion of the heavenly bodies from east to west. By this rapid movement, the inhabitants about its equator are carried at the rate of 1,042 miles an hour; and those on the parallel of London, about 580 miles. The earth's motion in its orbit, causes the apparent annual movement of the sun; and the plane of its orbit being inclined to that of the equator, which is the plane

of its diurnal motion, causes the difference of seasons and climates; and the inequality in the length of the days and nights. Besides its diurnal and annual revolutions, the earth has another motion called the precession of the equinoxes. This is a rotatory motion in the axis of the earth round the axis of the ecliptic. If the inclination of these axes remain the same, their revolution is accomplished in 27,000 years.

The seas and unexplored parts of the earth contain 160,522,026 square miles: the inhabited parts contain 38,390,569 square miles; Europe, 4,456,065; Asia, 10,768,823; Africa, 9,654,807; America, 14,110,874. In all, 199,512,595; the number of square miles on the whole surface of the globe.

The moon is a secondary planet attendant upon the earth, as her centre of motion, and near whom she is constantly found; so that, if viewed from the sun, she would never appear to depart from the earth, by an angle greater than 10.″ The moon revolves round the earth in twenty-nine days, twelve hours, and forty-four minutes, at the distance of about 240,000 miles. The orbit in which she performs this movement is an ellipsis. Her rate of motion, is about 2290 miles every hour. She revolves round her own axis in the same time that she goes round the earth; and, consequently, she has but one day and one night in the course of one of our months. The moon shines by reflecting the light of the sun; and sometimes a large portion of her disk is faintly illuminated by light reflected to her from the

earth; as when her crescent is brightly displayed, and the other part of her orb is faintly seen.

In consequence of her revolution round the earth, and the different positions in which she reflects the sun's light, the moon appears to experience a continual change of figure.

When the moon is in a line between the sun and the earth, her unenlightened side is turned towards us, and she is not visible; and is, then, called the new moon. When she has advanced through an eighth part of her orbit, a quarter of her enlightened hemisphere is turned towards the earth, and she then appears horned. When the moon has performed a fourth part of her course, she shows one half of her enlightened side, and is then said to be a quarter old.

When she is in her second octant, or eighth portion of her orbit, she displays a larger part of her illuminated hemisphere, and appears humped, or gibbous. When the moon has performed half of her revolution, she then exhibits the whole of her enlightened face, and is full. In her third octant, part of her dark side being turned towards the earth, she is again gibbous. Advancing farther in her decrease, one half of her enlightened side becomes apparent only. When she is in her fourth octant, only one quarter of her illuminated face is visible; and when she has completed her course, the moon again totally disappears. To the inhabitants of the moon the earth must assume the same appearances, but must be seen thirteen times larger.

It was long imagined that the moon had no

atmosphere; but it is now certain that she has an atmosphere, extending from her body, not farther than 5742 English feet.

Upon an average, the moon rises three quarters of an hour later each day than the preceding one; but about the fifteenth of September, she is so peculiarly situated, that for several successive evenings, she rises later each evening, only by from fifteen to twenty minutes.

To the inhabitants of the regions within the arctic and antarctic circles, the full moon never rises in their summer, when, for a long time, they do not lose sight of the sun; nor sets in their winter, when, for a gloomy season, they are not visited by that glorious luminary.

When viewed through the telescope, the face of the moon appears wonderfully varied; for those dark patches and brilliant spots which are visible to the naked eye, are seen to be immensely high mountains and deep concavities, and prodigiously prominent points. Volcanoes are discernible, and some astronomers assert, that they have seen their flames faintly gleaming. Her mountain scenery (says Dr. Brewster) bears a strong resemblance to the towering sublimity and terrific ruggedness of Alpine regions. Huge masses of rock, rise at once, from the plains, and raise their peaked summits high in air; while projecting crags spring from their rugged flanks, and, threatening the valleys below, seem to bid defiance to the laws of gravitation. Around the base of these frightful eminences, are strewed numerous loose and unconnected fragments, which time seems to have detached

from the parent mass. In some parts, the perpendicular elevation of the mountains is above four miles; and some of the immense hollows are nearly four miles deep, and forty miles in diameter.

QUESTIONS.

What is the form of the earth, and what station does it hold in the arrangement of the planets? What are the chief proofs of the earth's spherical figure? In what time, and at what distance from the sun, does the earth revolve around that glorious luminary? In what time does the earth perform its revolution round the sun? What is that movement of the earth which is called the precession of the equinoxes? What are the effects of the earth's diurnal and annual motions? What is the number of square miles on the earth's surface, and how are they distributed? At what rate does the earth perform her diurnal and annual motions? What secondary planet attends the earth round the sun; at what distance, and in what time, does she revolve round the earth? What is the rate of the moon's motion? By what light does the moon shine? What appearances does the moon assume in different parts of her course? How large must the earth appear to the inhabitants of the moon, and what figures must she present? Has the moon any atmosphere; and if so, what is its extent? What appearances does the moon present through the telescope? Does the moon revolve round her own axis; and if so, in what time? What is the length of the day and night in the moon?

CHAP. XIX.

ASTRONOMY — continued.

THE TIDES. — ECLIPSES.

Those risings and fallings of the water, which are observable on all sea-coasts, are called tides.

Were the waters of the ocean always at rest, they would always preserve a certain depth; but experience teaches that they are continually varying from this level, and that some of these variations are regular and periodical.

On the shores of the oceans, and in bays and harbours which communicate freely with the ocean, the waters rise above this mean height *twice* a-day, and as often sink below it; forming what is called a flood and an ebb, a high and a low water.

The whole interval between high and low water is called a tide; the water is said to flow and to ebb. The rising is named the flood tide, and the falling is called the ebb tide.

It is observed, likewise, that this rise and fall of the waters is variable in quantity; sometimes rising higher and sinking lower; and it is remarked, that these different heights of tide succeed each other in a regular series, diminishing from the greatest to the least, and then increasing from the least to the greatest. The greatest is called a spring tide, and the least is called a neap tide. This series is completed in about fifteen days; and two of these regular processes take place in the exact time of a lunation.

It is remarked, that high water happens at new and full moon.

The time of high water, in any place, appears to be regulated by the moon.

The interval between two succeeding high waters is variable.

The tides in similar circumstances, are greatest when the moon is at her smallest distance from

the earth; and, gradually diminishing, are smallest when she is at her greatest distance. The same holds good with respect to the sun's distance; and the highest tides are observed during the winter months of Europe.

The tides in any part of the ocean increase as the moon, by changing her declination, approaches the zenith of that place. The tides which happen while the moon is above the horizon, are greater than the tides of the same day, when the moon is below the horizon.

Such are the regular phenomena of the tides; which were observed by many of the ancient philosophers, but for which they could assign no adequate cause.

The first who gave any rational explanation of these phenomena, was Kepler; who asserted that "The orb of the attracting power, which is in the moon, extends to the earth, and draws the waters under the torrid zone; acting upon places where it is vertical; insensibly on confined seas and bays, but sensibly on the ocean, whose beds are large, and the waters have the liberty of reciprocation, that is, of rising or falling." And again, "The cause of the tides of the sea appears to be the sun and moon, drawing the waters of the sea. The waters of the ocean would all go to the moon, were they not retained by the attraction of the earth." He then explained the cause of the elevation of the waters at one and at the same time, immediately under the moon, and on the opposite side; remarking, that the earth is less attracted by the moon than the nearer waters, but more strongly by the waters

which are more remote. Upon this idea Sir Isaac Newton improved, and wrote so amply upon the subject, as to acquire for himself the honour of giving a complete explanation of the tides.

The attraction of the sun, as well as that of the moon, contributes to this alternate rising and falling of the waters which cover the larger portion of the surface of our globe; but as the sun is at so much greater distance from the earth, between ninety-five and ninety-six millions of miles, than the moon, which is only two hundred and forty thousand miles, the influence of the latter is by much the more powerful. At new and full moon, the sun and the moon act in the same line of direction with conjoined forces, and then the highest tides take place; but when the moon is in either of her quarters, she and the sun act in different directions, weakening each other's influence, and then the lowest tides happen.

This is invariably the case in such parts as lie open to the general ocean. In seas and channels which are confined or narrow, many different causes combine to produce deviation from these effects. Thus, it is high water at Plymouth, about six hours after the moon has passed the meridian; at the Isle of Wight, about nine hours; and at London Bridge, about fifteen hours. At Batsha, in Tonquin, the sea ebbs and flows but once a-day; the time of high water being at the setting of the moon, and the time of low water at her rising. Great variations in the heights of tides exist in different places,

produced by local circumstances; such as the situation of coasts, or the nature of the straits through which the waters are impelled. Thus, the Mediterranean and Baltic seas, having very scanty openings to the main ocean, have very slight tides; while at Bristol, the elevation is sometimes forty feet, and at Chepstow, eighty feet; because the water passes through very narrow channels, before it reaches those places.

In some parts, owing to the sharp turns and windings of rivers, and other peculiarities of situation, the tide rushes in suddenly and rapidly with great violence, foaming and roaring. It is then called a bore.

ECLIPSES OF THE SUN AND MOON.

All opaque bodies, when they are exposed to the light of a luminous body, cast a shadow behind them in an opposite direction. The earth is an opaque, or dark body; exposed to the light of the sun, casting a shadow from the side turned away from that luminary, which extends over a large portion of space, and to a great distance. Now, it is plain that when the moon passes through this shadow, she must be partially or entirely darkened, according as she traverses a smaller or larger part of it. This is called an eclipse of the moon

Again, when the moon passes between the sun and the earth so as to fall upon any part of its surface, the inhabitants of that part will be involved in darkness; and a dark spot will, to them, appear on the sun's disk, as long as the shadow covers them. But as the moon is much

less than the earth, and its shadow, consequently, can extend over only a small portion of its surface at the same time, there will be total darkness only in that part where the shadow falls; while in the neighbouring places, the inhabitants will see a greater or less part of the face of the sun obscured, in proportion as they are nearer to, or farther from, the shadow. This kind of obscuration, is called an eclipse of the sun. Eclipses of the sun, it is plain, from what has been said, are visible only at particular parts of the earth; but eclipses of the moon are observable from any part of the earth, above whose horizon she is, at the time when the eclipse takes place.

There can be no lunar eclipse, it is evident, therefore, but at full moon, when she is opposite to the sun, the earth being between her and the sun; and that an eclipse of the sun can never happen but at new moon, that is, when the moon is between the sun and the earth; for it is only at such periods that the earth and moon are in a straight line with the sun, or that the shadow of the one can fall upon the other. But as there is a new and a full moon every month, it might naturally enough be expected that one eclipse of the sun, and another of the moon, should take place every month. Yet this is far from being the case; for there are but few eclipses in comparison of the new and full moons. This is owing to the obliquity of the moon's orbit with that of the earth; for were their orbits coincident, the moon would then pass through the middle of the earth's shadow, and be eclipsed at

every full; and, in like manner, the moon's shadow falling upon some part of the earth, would occasion an eclipse of the sun at every time of new moon. But one half of the moon's orbit is elevated about five degrees and one-third, above the plane of the ecliptic, and the other half as much depressed below it; therefore, the moon can never be in the same plane with the earth but when she is in one or other of the two points, where their orbit intersects that of the earth, which points are called the nodes. And, therefore, as the moon may make many revolutions round the earth before a new, or full moon takes place in one of those points, it is plain that there may be no eclipse, either of the sun, or the moon, in the space of several months. When the sun and moon are more than seventeen degrees from either of the nodes at the time of their conjunction, the moon is then generally too high or too low in her orbit for any part of her shadow to fall upon the earth; and when the sun is more than twelve degrees from either of the nodes at the time of opposition, the moon is commonly too high or too low in her orbit to pass through any part of the earth's shadow. Thus, in both these cases, there will be no eclipse. But when the moon is less than seventeen degrees from either node at the time of conjunction, a greater or less portion of her shadow will fall upon the earth, as she is more or less within this limit; and when she is less than twelve degrees from the node at the time of opposition, she will go through a greater or less portion of the earth's shadow, according to her

situation. Then, as the sun commonly passes by the nodes but twice a year, and as the moon's orbit contains 360 degrees, of which seventeen, the limit of solar eclipses, and twelve, the limit of lunar eclipses, are but small portions, it is obvious that there may be many new and full moons without any eclipses.

QUESTIONS.

What are tides? What are ebbings and flowings of the tide? What are spring and neap tides, and when do they respectively take place? How is it that two spring tides take place at the same time, in two opposite points of the surface of the earth? What appears to be the immediate causes of the tides? What irregularities are there in their times and their elevations, and what are the causes of those irregularities? What occasions the spring and the neap tides? What is a bore? What occasions eclipses of the sun? What causes eclipses of the moon? When do eclipses of the sun and moon take place? Why is there not an eclipse of the sun at every new moon? Why is there not an eclipse of the moon at every full moon?

CHAP. XX.

ASTRONOMY—continued.

Next in order of distance from the sun is the planet Mars. He is of a fiery red colour, and always reflects a much duller light than that of Venus. This planet is not subject to the same limitations in his movements as Mercury or Venus; but appears sometimes near the sun, and sometimes at a great distance from him; sometimes rising when the sun sets, or setting

when he rises. The distance from the sun is calculated to be 125,000,000 of miles. He revolves around that luminary in 686 days, 23 hours, of our measurement of time, moving at the average rate of 47,000 miles an hour; and moves round his own axis from west to east in somewhat more than twenty-four hours. By his diurnal motion the equator of Mars is carried round at the rate of 556 miles every hour. His quantity of light and heat is equal to only about one half of that which we receive; and, to his inhabitants, the sun must appear but half as large as he does to us. No moon has as yet been found attending him. He is sometimes of a gibbous form, but never horned; sometimes half, or three-quarters illuminated, but never full; which proves that his orbit includes that of the earth, and that he shines by reflected light. Our globe and the moon must appear to Mars, like two moons, a larger and a smaller, changing places with each other; appearing, sometimes horned, sometimes half or three-quarters illuminated; but never full, nor ever more remote from each other than one quarter of a degree. To the inhabitants of Mars, the earth must appear as large as Venus does to us, and never more distant from the sun than forty-eight degrees. Dark spots have been observed upon the surface of this planet; and bright spots about his poles. Of all the planets, Mars is most like the earth. Its diurnal motion is nearly the same; the obliquity of his ecliptic not very different; and, when compared to the other planets, his distance from the sun and the time of his revo-

lution round that glorious body, most resemble those of the earth. Mars appears to be surrounded by a considerable atmosphere; belts have also been observed on his disc.

Jupiter was formerly ranked as next in distance from the sun; yet his distance from that luminary was observed to be disproportionate to that of Mars, of the Earth, and of Venus, so that some astronomers conjectured there must have been another planet between him and Mars, lost by some violent operation; or that some planet or planets actually existed in that space. This latter circumstance is now found to be the fact. Modern astronomy has discovered four very small globes moving round the sun, in orbits between those of Mars and Jupiter. But as Herschel, and other astronomers, seem to regard them as differing from the rest of the planets, the consideration of them may be deferred, till the description which astronomy gives of the primary planets be finished. Jupiter is the brightest of the planets, excepting Venus, and he exhibits the same appearance of belts on his surface, as does Mars; but they are much larger and more permanent. The number of these belts is very variable; as sometimes only one can be discerned, and at other times eight are discernible. They are generally, but not always, parallel to one another; their continuance is very uncertain, as they sometimes remain unchanged for three months together, and, at other times, new belts have been formed in a few hours. Jupiter is the largest of the planets. His diameter is 81,000 miles, which is a thou-

sand times more than that of the earth. At the distance of 426,000,000 of miles he revolves round the sun in eleven of our years, three hundred and fourteen days, and twelve hours, at the rate of 25,000 miles an hour. He moves round his own axis, from west to east in nine hours and fifty-six minutes. By this amazingly rapid rotation, his equator is carried round 25,920 miles every hour. The figure of this planet is an oblate spheroid; and the plane of his equator is very nearly coincident with that of his orbit; so that its inhabitants can know very little difference of seasons. To them, the sun must appear but one twenty-eighth part as large as he does to us, and the light and heat they receive from that luminary, are comparatively small in proportion to what we enjoy. But to counterbalance this apparent disadvantage, Jupiter is attended by four moons, some larger, and some smaller than the earth. The first of these his satellites at 229,000 miles distance from his centre, revolves round him in one day, eighteen hours and thirty-six minutes of our time. The second is distant from the planet 364,000 miles, and goes round him in three days, thirteen hours, and fifteen minutes. The third performs its revolution in seven days, three hours and fifty-nine minutes, at the distance of 580,000 miles, and the fourth, at the distance of 1,000,000 of miles from his centre, in sixteen days, eighteen hours, and thirty minutes. These are sometimes seen to pass over the disc of Jupiter like dark spots. The three moons of Jupiter nearest to his body, pass through his

shadow in every revolution they make round him; and by means of their eclipses, astronomers have discovered that the light from the sun reaches the earth in eight minutes, and have also determined the longitudes of various places on our globe, with greater facility and certainty, than by any other method yet known.

Saturn, the next planet in the system, is distant from the sun, 780,000,000 miles, and moving at the rate of 18,000 miles an hour, performs his revolution round that glorious star, in twenty nine years, one hundred and sixty-seven days, and five hours of our time. Its diameter is 67,000 miles, and consequently this planet is six hundred times as large as the earth.

Saturn has round him a thin broad ring, which appears double when viewed through a powerful telescope, and when it exhibits this appearance, the inner ring is brightest. The breadth of this ring is 21,000 miles, and its distance from the body of the planet is the same. Herschel has proved that the ring revolves in its own plane, in ten hours, thirty minutes, and fifteen seconds. The light of the ring is generally more vivid than that of the planet. As the plane of this ring keeps always parallel to itself, it disappears twice in every revolution of the planet, that is, about once in fifteen of our years, and he sometimes appears quite round for nine successive months. At other times, the distance between the body of the planet and the ring is very perceptible. When viewed from Saturn, it must appear like a vast luminous arch in the heavens; visible and invisible in turn, for fifteen years.

The axis of Saturn is probably inclined to the ring. This planet receives only one-ninetieth part of the light and heat of the sun, which we do. Herschel gives the following dimensions of the two rings, with the space between them,

	Miles.
Inner diameter of the smaller ring, -	146,345
Outside diameter of the same, - - -	184,393
Inner diameter of the larger ring, -	190,248
Outside diameter of the larger ring, -	204,883
Breadth of the inner ring, - -	20,000
Breadth of the outer ring, - -	7,200
Breadth of the vacant space between the two rings, - - - -	2,839

Herschel supposes that the ring consists of as solid materials as Saturn itself. It casts a very strong shadow upon that planet.

Seven moons revolve round Saturn, which supply him with light during the absence of the sun. They are so small, and at such a distance from the earth, that they cannot be seen but through very powerful telescopes. The sixth and seventh, discovered by Herschel, are the smallest. The fourth is the brightest. Saturn is still more flattened at the poles, than even Jupiter. This circumstance appears to be occasioned by its ring; which being in the plane of its equator, and equally as dense as the planet itself, acts more powerfully upon the equatorial regions of Saturn than upon any other part of his disc; and by diminishing the gravity of those parts, it aids the centrifugal force in flattening the poles of the planet.

QUESTIONS.

What is the appearance of the planet Mars? At what distance from the sun, and in what time does Mars revolve round that luminary, and at what rate of motion? In what time, and at what rate, does Mars turn round its own axis? What quantity of light and heat does he receive from the sun in proportion to what the earth does? Has Mars any moon attending him? What appearances of figure does Mars present at different times? What spots have been observed upon the surface of Mars? In what respects does Mars resemble the earth? How is Jupiter situated from the sun? What are the size and brightness of Jupiter, and what peculiar appearances are observed upon his disc? How many moons attend Jupiter? What are the respective distances of Jupiter's satellites from his body, and what are their times of revolution? At what distance from the sun, and in what time, and at what rate, does Jupiter revolve round him? In what time, and at what rate does Jupiter revolve round his own axis? What use have astronomers made of the eclipses of Jupiter's satellites? At what distance from the sun, in what time, and at what rate does Saturn perform his annual revolution? What is the diameter of Saturn? What is the nature of the ring round Saturn? How many moons has Saturn? What is the figure of Saturn? What is the apparent cause of Saturn's being very much flattened at the poles? What are Dr. Herschel's measurements of the rings of Saturn?

CHAP. XXI.

ASTRONOMY — continued.

THE FIVE NEW PLANETS.

From certain inequalities in the motions of Jupiter and Saturn, some astronomers had in-

ferred that there existed beyond the orbit of Saturn, some planet by whose action those inequalities were produced.

This supposition was confirmed by the discovery which Dr. Herschel made of a new planet in 1781. In compliment to the king his patron, he named it the Georgium Sidus, though, on the Continent, it is better known by the name of Herschel, or Uranus.

This planet is distant from the sun, 1800,000,000 of miles, and performs its sidereal revolution round the sun in eighty-three years, 150 days and 18 hours. Its diameter is 35,112 English miles. The Georgium Sidus, being at a vast distance from the sun, can scarcely be distinguished by the naked eye. When the sky is very serene, however, it appears like a fixed star, of the sixth magnitude, shining with a bluish white light, and a brilliancy between that of Venus and the Moon. Six satellites have been discovered also, by Herschel, revolving round this distant planet, supplying its deficiency of light received from the sun.

The planet Ceres was discovered by the astronomer Piazzi, at Palermo, in 1801. It is of a ruddy colour, and appears about the size of a star of the eighth magnitude. It seems to be enveloped by a thick atmosphere. Ceres performs her revolution round the sun in four years, seven months, and ten days, and her mean distance from that luminary is nearly 260,000,000 of English miles. According to the measurement of Dr. Herschel, the diameter of Ceres does

not exceed 160 miles, while the German astronomer, Schroeter, computes it to be 1624 miles.

The planet, named Pallas, was discovered by Dr. Olbers, at Bremen, in Lower Saxony, A.D. 1802. It is nearly of the same magnitude as Ceres, but of a less ruddy colour, is surrounded by a nebulous atmosphere of almost the same extent, and performs its annual revolution in about the same period, of four years, seven months, and ten days. It is distinguished, in a very remarkable manner, from Ceres, and all the other primary planets, by the immense inclination of its orbit, for it ascends above the plane of the Ecliptic, at an angle of about thirty-five degrees; which is five times greater than the inclination of Mercury. The orbits of Ceres and Pallas intersect each other, a circumstance which does not take place in any other part of the solar system.

The planet, called Juno, was discovered by Harding, at the observatory of Lilienthal, near Bremen, in 1804. This planet is of a reddish colour, and free from the nebulosity which surrounds Pallas. Its diameter is less, and its distance greater, than those of the other three proximate planets. This planet performs its revolution round the sun in somewhat more than five years. Its mean distance from the sun is 275,000,000; its diameter, 1425 miles.

In 1807, Dr. Olbers discovered another planet, to which he gave the name of Vesta. It is about the fifth or sixth magnitude, and may be discerned by the unassisted eye, in a clear state of atmosphere. Its light is more intense, pure and

white, than that of the other three. The orbit of Vesta cuts the orbit of Pallas, but not in the same place where it cuts that of Ceres. Its revolution round the sun is performed in somewhat more than three years.

QUESTIONS.

When was the Georgium Sidus discovered, and by whom? What is it usually called on the Continent? At what distance is the Herschel from the sun, and in what space of time does it perform its revolution round the sun? What is its diameter? Is the Georgium Sidus distinguishable by the naked eye? Has the Herschel any moons? When and by whom was the planet Ceres discovered? At what distance from the sun, and in what time, does Ceres perform her revolution? What is the diameter of Ceres? When, and by whom, was the planet, called Pallas, discovered? What is the magnitude of that planet, and what is its appearance? For what is Pallas principally remarkable? When was Juno discovered, and by whom? What is its appearance? At what distance from the sun, and in what time, does Juno perform her revolution round that glorious luminary? When, and by whom, was the Vesta discovered? What is its appearance? In what time does Vesta accomplish her solar revolution?

CHAP. XXII.

ASTRONOMY—continued.

COMETS — SYSTEMS.

COMETS are bodies which revolve round the sun, but in very eccentric orbits, and therefore appear in the heavens only occasionally. They exhibit no defined disc, but shine with a pale

and cloudy light; and are accompanied by tails or trains, turned from the sun. When viewed through glasses of high power, a comet resembles a mass of aqueous vapours encircling an opake nucleus, of different degrees of darkness in different comets; but, in some, no nucleus is discernible.

In its advance towards the sun, the faint cloudy light of the comet becomes more brilliant, and its luminous train gradually increases in length. When it comes to that part of its orbit which is nearest to the sun, the length of its tail reaches its utmost point, and its lustre sometimes equals that of Venus. As it departs from the sun, it loses its splendour gradually, till it resumes its nebulous appearance, and its train decreases. It continues diminishing till it reaches such a distance from the earth, as no longer to reflect the sun's light with strength sufficient to render it visible to human eyes.

Travelling unseen through the remoter parts of its orbit, the comet pursues its course far beyond the limits of our system. After the lapse of years, it is again seen returning to our system, and tracing a portion of the same orbit round the sun which it had formerly described.

During the dark gloomy night of barbarism and error, comets were regarded with terror, as the harbingers of calamity and ruin. Even so late as the beginning of the eighteenth century, they were considered by some to be the seats of woe and punishment, destined for the wicked, in which they would experience the extremes of heat and cold. By others, comets

were supposed to answer more scientific purposes. It was imagined that they conveyed back to the planets the electric fluid which is constantly dissipating, or supplied the sun with fuel which is constantly consumed. One astronomer thought that the deluge was occasioned by the train of vapours of a comet involving the earth, and condensing into rain upon its mountains. Indeed, if our globe were to receive a shock from one of those bodies, the consequences would be dreadful. A new direction would be given to the rotatory motion of the earth, which would revolve round a new axis. The ocean, forsaking its natural situation and bed, would be impelled by the centrifugal force to the new equatorial regions. Continents and islands would be covered by the universal rush of the waters, and all the works of men, together with men themselves, would be destroyed. But though there be a possibility, there is no probability of such an event occurring. The trains of comets sometimes spread over an immense space in the heavens; even thousands of miles.

Various opinions have been entertained by astronomers concerning the nature of these trains of light. Some supposed that they were occasioned by the light of the sun, transmitted through the nucleus of the comet, which they believed to be transparent like a lens. Some imagine them to be streams of electric matter; while others judged them to be vapours raised from the body of the comet, by the action of the sun's heat. Sir Isaac Newton had the hon-

our of showing, that comets revolve round the sun in excentric ellipses, extending far beyond the orbits of the other planets of our system.

The mundane system, which places the sun in the centre, and represents the planets as moving round him, and which is now fixed upon an immoveable foundation, was taught in a very early age of the world, by the celebrated philosopher, Pythagoras. After having been lost for a long time, it was revived by Copernicus, and completely established by Newton.

From these three illustrious men, by whom it was embraced and supported, it is named the Pythagorean, the Copernican and the Newtonian system. Two other systems have been devised, both of which have fallen before the force of reasoning and demonstration. The first is the system of Ptolemy, an Egyptian philosopher, who lived about one hundred and thirty years after the birth of our Saviour. He supposed the earth to be fixed as the centre of the planetary movements; and the other planets, in the number of which he reckoned the sun, to revolve round it. Above these, he placed the firmament of fixed stars, the crystalline orbs, the primum mobile, or first mover; and, over all, the heaven of heavens. All these vast bodies, at immense distances, he supposed to move round the earth once in every twenty-four hours. He conceived that each fixed star was set in a transparent sphere, of a substance like crystal; and to account for their various apparent movements, he was obliged to invent a number of circles crossing one another in all directions.

Tycho Brahe, a Danish astronomer, who flourished towards the end of the sixteenth century, supposed the earth to remain at rest, and the sun, with all the planets, to revolve around it in the space of one year; while the latter, by their individual motions, are carried round the sun in their respective periods, accompanying that luminary in his course round the earth.

QUESTIONS.

What are Comets? What appearance have they when viewed through good telescopes? What changes in the appearances of comets are produced by their approximation to the sun, and their departure from that luminary? What opinions have been entertained concerning Comets? What are the trains of comets supposed to be? What effects would probably take place were our globe to receive a shock from a comet? What is the Pythagorean, Copernican, or Newtonian system? What is the Ptolemean system? What is the system of Tycho Brahe?

CHAP. XXIII.

GEOGRAPHY.

THE term Geography is compounded of two Greek words, signifying the earth, and a writing or description. Geography describes the surface of our globe; its various regions, mountains, oceans, seas, rivers, cities, products of countries, and manners of their inhabitants.

Geography considers the surface of the earth as consisting of land and water. The water occupies two thirds of the earth's surface. The

land is divided into continents, islands, peninsulas, isthmuses, promontories and capes.

The divisions of the water are, oceans, seas, straits, gulfs, bays, rivers and creeks.

The different regions of the earth are arranged under four grand divisions, or as, they are commonly called, quarters, namely, Europe, Asia, Africa and America.

A continent is a large extent of land not divided by any great accumulation of waters. There are two continents, the eastern continent, containing Europe, Asia and Africa; and the western continent, containing America.

An island is land entirely surrounded by water. A peninsula is land almost surrounded by water. An isthmus is a neck or bridge of land, connecting a peninsula with a continent, or two parts of a continent.

A promontory is high land advancing into an ocean or a sea. The extreme point of a promontory is called a cape.

An ocean is a vast collection of water, not separated by any considerable portions of land. The oceans which occupy a very large portion of the face of our globe, are the Pacific; the Atlantic; the Indian Ocean; the Arctic, Northern, or Frozen Ocean, surrounding the north pole; the Antarctic, or Southern Ocean, surrounding the south pole. A sea is water almost surrounded by land. A gulf is a portion of an ocean or a sea, protruding itself into the land, narrow at its mouth, or entrance, but widening to a much greater extent within.

A bay is a portion of an ocean or sea running into the land, wider at its opening than in the internal part. A strait is a narrow portion of water connecting a sea with an ocean, or two seas. A lake is water surrounded by land. A river is water rising in the land, and flowing into the sea.

Of the four large divisions of the earth, Europe is the smallest but the most important, on account of superiority in science, arts and manufactures, activity and enterprize. Its population amounts to about 150,000,000. Asia is the most populous, being supposed to contain 500,000,000 inhabitants. Asia was the parent of nations and civilization, and has been the scene of the most interesting events in the history of mankind.

Africa was, in early periods of the world, of far greater importance than at present. Its northern coasts were well cultivated, and very populous. There flourished Egypt, the cradle of the arts, and there the powerful commercial state, Carthage, the rival of imperial Rome. Now, it is involved in the thickest shades of darkness and ignorance. Its present population is computed at 30,000,000.

The continent of America is the largest of the four grand divisions, and is called the new world, because not known to the civilized regions of the earth until the fifteenth century. As comparatively a small portion of it is cultivated, the population of this quarter of the globe is low; being estimated at only 20,000,000.

QUESTIONS.

What is geography? What are the divisions of the land? What are the divisions of the water? What is a continent? An island? A peninsula? An isthmus? A promontory? A cape? What is an ocean? A sea? A strait? A lake? A gulf? A bay? A river? What are the four principal divisions of the regions of the Earth? Which of them compose the eastern, and which the western continent? Which of them is called the new world? What are the respective characteristics of the four grand divisions or quarters of the globe? What calculation is made of their respective population?

CHAP. XXIV.

GEOGRAPHY—continued.

EUROPE is bounded, on the north, by the Arctic Ocean; on the east, by the Uralian mountains, and the rivers Volga and Don; on the south, by the Mediterranean Sea, and on the west, by the Atlantic Ocean. The greater part of Europe is situated in the north temperate zone, and is therefore free from the excessive heats, the violent rains, and furious hurricanes of the tropical regions. The Christian religion is established throughout Europe, excepting in that part which is still possessed by the Turks, where Mahometanism prevails.

The principal seas of Europe, are, the White Sea, the Baltic, and the Mediterranean. The White Sea has been but little explored. It contains a number of islands which are, as yet,

not well known. The Baltic, spreading widely towards the north-east, forms the gulfs of Bothnia and Finland, both of which are frozen up during the four or five months of the northern winter. Its waters are not very salt; nor are they greatly influenced by the tides; nor do they abound much in fish.

The Mediterranean has been, in all ages, the centre of civilization. The rocks of Ceuta, or Abyla, in Africa, and of Calpe, in Spain, called by the ancients, the pillars of Hercules, constitute the western boundaries of this great inland sea; its eastern boundary being the coast of Asia Minor, and the part of this sea which bathes that coast is named the Levant. It is about 2000 miles in length. Branching out northward, the Mediterranean forms two great gulfs; that of Venice, or the Adriatic, and the Archipelago, or Egean Sea. Flowing through the strait called the Hellespont, it expands into the sea of Marmora, the ancient Propontis. The Mediterranean abounds with fertile and beautiful islands, and is surrounded by rich and fertile coasts. Excepting in the narrow straits, this sea experiences not the variations of the tides, so as to be discernible. It has a vast abundance of various kinds of fish, and furnishes large quantities of coral, red, white, and vermillion.

The chief rivers of Europe, are the Neva, the Neiper, the Don, or Tanais, the Thames, the Elbe, the Oder, the Vistula, the Rhone, the Seine, the Rhine, the Danube, the Tiber. The principal islands of Europe, are Iceland, Zealand, Great Britain, Ireland, Corsica, Sardinia, Sicily,

Iviça, Majorca, Minorca, Malta, Candia. The chief mountains of Europe are, the Dofrafield, between Sweden and Norway; the Carpathian, between Poland and Hungary; the Alps, between France, Germany and Italy; the Pyrenees, between France and Spain; the Appenines, running from north to south through Italy. Its volcanos, are Hecla, in Iceland; Etna, in Sicily; and Vesuvius, in Italy. The states and kingdoms of Europe, are,

NORTH.	CHIEF TOWNS, &c.
Lapland - - -	Kimi, Tornea.
Sweden - - -	Stockholm, Calmar, Upsal, Lund, Carlscron.
Norway - - -	Wardlaus, Bergen, Drontheim, Christiana.
Denmark - -	Copenhagen, Wyburg, Odensee, Altona.
Northern Russia	Petersburg, Revel, Archangel, Riga.
MIDDLE.	
British Empire -	London, Edinburgh, Dublin, Bristol, York, Liverpool, Manchester, Birmingham.
Holland, with part of Belgium -	Amsterdam, Hague, Brussels, Antwerp.
Northern Germany	Hanover, Hamburg, Lubec, Dresden, Cassel, Brunswick.
Prussia, with part of Poland -	Berlin, Frankfort, Dantzig, Warsaw.
Middle Russia -	Moscow, Novogorod.

MIDDLE.	CHIEF TOWNS.
France	Paris, Rouen, Lyons, Brest, Toulon, Marseilles, Bordeaux.
Switzerland	Berne, Lucerne, Zuric, Geneva.
Southern Germany	Stutgard, Munich, Ulm, Ratisbon, Ingolstadt.
Austrian Empire	Vienna, Prague, Presburg, Inspruck, Venice, Milan, Cracow.
Southern Russia	Cherson, Scbastipol, Wilna.
SOUTH.	
Portugal	Lisbon, Oporto.
Spain	Madrid, Cadiz, Ferrol, Grenada, Valencia, Bilboa.
Italy	Rome, Genoa, Turin, Florence, Leghorn, Naples.
Turkey in Europe	Constantinople, Belgrade, Adrianople, Iannina.

QUESTIONS.

How is Europe bounded? What religion prevails most extensively in Europe? Which are the principal seas of Europe? What are the chief rivers of Europe? The chief islands of Europe? The mountains and volcanos? Which are the states and kingdoms of Europe, and how are they arranged? What are the principal cities of the various states of Europe?

CHAP. XXV.

GEOGRAPHY — continued.

Asia is bounded by the Arctic ocean, north; by the Uralian mountains, the river Volga, the Black Sea, the Archipelago, the Levant, and the Arabian Gulf, west; and east and south, by the Pacific Ocean.

It is 7000 miles long, and about 5000 miles broad.

The oceans and seas belonging to Asia, are the Arctic, the Indian, and the Pacific Oceans; the Black Sea, the Caspian, the seas of Corea, Tonquin, and Siam; the Bay of Bengal, the Arabian, or Red Sea; the Persian Gulf, the Levant, and the Archipelago.

The chief rivers of Asia, are the Obi, the Lena, the Yenisei, the Amur, the Tigris, the Euphrates, the Indus, the Ganges, the Burrampooter, the Ava, the Meinam, the Kian Ku, the Hoan Ho.

The principal mountains are, Taurus, Caucasus, Ararat; the Uralian; the Altaian, Lebanon, Sinai; the Thibet, or Himmalay mountains, some of which are the loftiest known upon the earth; Belur Tag; the Ghauts of Hindûstan.

The chief islands of Asia are, Ceylon, Borneo, Sumatra, Java, and the other islands of the eastern archipelago; Australasia, or new Holland, the largest island known; Polynesia, or the islands in the Pacific Ocean; the Japanese islands, which constitute a powerful empire, near the eastern extremity of Asia.

The states and kingdoms of Asia may be thus arranged conveniently:

NORTH.	CHIEF CITIES.
Siberia, or Asiatic Russia -	Tobolskoi, Yakutsk, Awatska, Orenburg.
MIDDLE.	
Turkey in Asia	Bursa, Smyrna, Aleppo, Damascus, Jerusalem, Bagdat.
Independent Tarttary - -	Sarmarcand, Balk.
Chinese Empire	Pekin, Nankin, Canton.
Empire of Japan	Jeddo, Miaco, Nagasaki.
SOUTH.	
Arabia - -	Mecca, Medina.
Persia - -	Ispahan, Tahira, Derbent, Baku.
Hindûstan -	Delhi, Agra, Calcutta, Bombay, Seringapatam.
Birman empire -	Ummerapoora, Pegu, Rangoon.
Malacca -	Malacca.
Siam - -	Siam, Bankok.
Laos - -	Leng.
Cambodia -	Cambodia.
Siampa - -	Feneri.
Cochin China -	Huefo.
Tonquin -	Kesho.

Africa is an immense peninsula, bounded on the north, by the Mediterranean; on the west, by the Atlantic; on the south, by the Southern Ocean, and on the east, by the Red Sea, and the Indian Ocean. From its southern extremity to the Mediterranean, it extends 4,200 miles, and its breadth from west to east, in that part which lies under the equator, is 4,140 miles. The pre-

vailing religion in the inhabited portion of Africa, is the Mahometan. Paganism extends its influence chiefly among the negro tribes; and comparatively a very small part of the population of Africa professes a corrupted species of Christianity. Throughout Africa, the government is despotism, and civilization is in a very low state. The climate of the greater part of Africa is excessively hot. It possesses few lakes, or navigable rivers. The chief rivers are the Nile, the Niger, and the Senegal. The only lake deserving of notice is named Maravi. The chief mountains of Africa are, Atlas, in the north; in the east, the mountains of Abyssinia, and in the south, those of the Cape of Good Hope. A very lofty ridge, called the mountains of the moon, is supposed to traverse the centre of Africa.

Immense deserts, or oceans of sand, interspersed with small islands of verdure, called oases, form a striking feature of this extraordinary country. The chief of these is called Zaara, or the great desert, which extends from the Atlantic, almost to the confines of Egypt; a space of 2,500 miles, by a breadth of 720. The principal regions of Africa, which are known are,

	CHIEF CITIES.
Egypt - -	Cairo, Alexandria, Girgé, Rosetta.

Mahometan states in the north, comprehended under the general name of Barbary:

Tripoli, Tunis, Algiers, and Morocco.

These are maritime piratical powers. They yield a nominal submission to the grand sultan,

Morocco extends along the shore of the Atlantic. It is a most fertile country, whose principal cities are Morocco, Fez, Tetuan, Tangier.

South of these are Bildulgerid and Segulmessa. The chief towns are Dara, Tafilet, Guergela, Vighig.

A large portion of the western coast of Africa is occupied by part of the great desert, Zaara. South of this desert are the tribes who inhabit the shores of the Senegal and the Gambia; the Jalofs, an active, warlike race, esteemed to be the best formed of the Negro race; Mandingos, widely diffused, mild and peaceable, and clothed in cotton garments manufactured by themselves; the Foulahs, with tawny complexions, pleasing features, and silky hair. Proceeding southwards, Upper Guinea, and Lower Guinea present themselves to notice. In the former, are, Sierra Leone, an English settlement formed for the benevolent purpose of teaching the Negro tribes to cultivate their lands, to traffic in the rich products of their soil, and to forsake the abominable trade in slaves; the Foulahs of Guinea, whose capital city is called Teembo, who have iron mines, manufactures of leather, silver and wood, and can muster 16,000 cavalry; the Grain coast, the Tooth coast, the Gold coast, the Slave coast, in which is Christianburg, belonging to Denmark, are regions on the coasts of Guinea, named according to their respective articles of commerce. Next to these is Benin, whose inhabitants enjoy some degree of civilization, who have a capital city of the same name, and can raise an army for defense, of 100,000 men.

In Lower Guinea, the next division of Africa to the south, are Loango, an extensive country, whose chief town is named Bouali; Congo, whose capital is St. Salvador, founded by the Portuguese, who colonized part of the country; which has a fertile soil, watered by the Zair, a large and rapid river; Matamba, and Angola, in which is a town called Loanda; Benguela, and a number of savage tribes wandering over a wild and unexplored country.

The southern portion of Africa, the region about the Cape of Good Hope, was colonized by the Dutch. It is about 550 miles in length, and 233 in breadth. Through this extent, the plantations are thinly scattered. The natural inhabitants are called Hottentots, a mild and gentle, but slothful, ignorant and stupid race. The colony is now become British, and both the country and people are fast improving, under wise and benevolent government.

On the eastern coast of Africa, next to the Cape colony, are Cafraria, whose inhabitants are as yet uncivilized and barbarous; and Natal, a country of which very little is known to Europeans. Mocaranga, or Monomotapa, a kingdom somewhat civilized, comes next, northward, in which the Portuguese have settlements; then, follow Sofala; Zanguebar, a marshy country abounding in elephants, in which is a large city, called Melinda, a Mahometan state, subject to the Portuguese; the coast of Ajon, chiefly possessed by Moors or Arabs; Brava; Magadasho, and Adel, in the latter of which are the towns Auzagurel, and Zeila, a port on the Red Sea. Contiguous to these, northward, is Abys-

sinia, a very ancient and powerful kingdom, which seems to have been peopled from Arabia. Its kings claim a descent from Solomon, by the queen of Sheba. The religion of the country is Christianity, miserably debased and corrupted; the language is a branch of the Arabic. The capital city is Gondor, containing about 50,000 inhabitants. In this country is one source of the Nile; and it is rich in animal and vegetable productions. The people are still in a wretched state of barbarism.

Between Abyssinia and Egypt, is Nubia, whose capital is Sennaar.

In the central parts of Africa, known to Europe, are the Moorish kingdoms of Ludemar and Beeroo; chief towns, Benowm and Walet; the city of Tombuctoo, or Timbuctoo, of the size and wealth of which extravagant accounts are given by the Moors; the Negro kingdoms of Kartu and Bambarra, whose capital is Sego, a considerable city, containing 30,000 inhabitants; Fezzan, Darfour, and a variety of insignificant tribes and states.

The African islands are, in the Atlantic Ocean, the Azores, the Madeiras, the Canary isles, Cape Verd islands, St. Matthew, St. Thomas, Fernando Po, Annabon, Ascension, and St. Helena. In the Indian Ocean, are Socotra, the Mauritius, Madagascar, a very large island, uncivilized by European connections.

QUESTIONS.

What are the boundaries of Asia? What is the extent of Asia? What are the chief rivers of Asia? What oceans and seas belong to Asia? What are the chief

mountains of Asia? Its islands? What are the states and kingdoms of Asia, and how are they arranged? What are the boundaries of Africa? What is its extent? What states does the Barbary coast include? What are the chief lakes and rivers of Africa? What are the chief mountains of Africa? What are the chief towns of Egypt? What is the capital of Abyssinia? What are the chief towns of Morocco? What are the chief islands of Africa?

CHAP. XXVI.

GEOGRAPHY—continued.

America, the largest division of the earth, extends, from north to south, nearly 9,000 miles; and in some parts, from east to west, more than 4,000 miles. It consists of two immense tracts, called North and South America, connected by a comparatively narrow neck of land named the Isthmus of Panama, or Darien.

NORTH AMERICA.

In North America, the principal rivers are the Missouri, the Mississippi, the Ohio, the St. Lawrence. The chief lakes, some of which are immensely large, are the Huron, the Michigan, Ontario, Lake Superior, Lake Winnipeg. The chief mountains are the Apalachian, and the Stony Mountains, which are not remarkably lofty: those of Mexico, and the isthmus of Panama, are far more elevated.

The lakes are so extensive as to merit the

name of seas. Lake Superior is 1,500 miles in circumference; its waters are clear and pure; it receives the tribute of thirty rivers, and abounds with islands, one of which, called Minoug, is sixty miles long. The rivers, also, are of exceeding magnitude. The Mississippi runs a course of 3,000 miles; and the Missouri, of 3,090.

The political divisions of North America, are the British Possessions, the United States, the Spanish dominions.

The British Possessions comprehend,

	CHIEF TOWNS.
Canada - - - -	Quebec, Montreal.
New Brunswick - -	Frederic, St. Anne.
Nova Scotia - -	Halifax, Shelburn.
Cape Breton - -	Sidney, Louisbourg.
Newfoundland - -	St. John, Placentia.
Bermudas - - -	St. George.

UNITED STATES.

Northern States, or New England; of which division the chief city is Boston.

Vermont, New Hampshire, Massachusetts, Connecticut, and Rhode island.

Middle States, of which the chief city is Philadelphia, New York, New Jersey, Pennsylvania, Delaware, and the territory on the north-west of the Ohio.

Southern States, of which the chief city is Charlestown.

Maryland, Virginia, Kentucky, North and South Carolina, Georgia, Tènassee, the Floridas, and Louisiana.

The other principal cities are Washington, the capital; New York; Baltimore, in Maryland; Wilmington, in North Carolina; Savannah, in Georgia; Pensacola, in Florida; New Orleans, in Louisiana.

SPANISH DOMINIONS.	CHIEF TOWNS.
New Mexico - - -	Santa Fé.
Mexico, or New Spain - -	Mexico.

The population of the large and handsome city, Mexico, is computed at 140,000.

In the Spanish territories of North America, are, likewise, the towns of Acapolco, and Vera Cruz.

SOUTH AMERICA.

The principal rivers of South America, are the Maranon, or Amazon, which is esteemed to be the largest, though not the longest river in the known world; the Orinooco, into which flow many great rivers, and which communicates with the Maranon by three lateral streams, forming a wonderful natural inland navigation; the La Plata, which is navigable for twelve hundred miles, which has in it numerous islands, and in which is a cataract called Parana, consisting of a series of falls extending through the space of twelve leagues, in the midst of fantastic and tremendous rocks.

In South America are numerous ridges of very lofty mountains, the chief of which is that of the Andes, which extends, from north to south, on the western side, 4,600 miles. This amazing ridge abounds in most elevated summits and dreadful volcanos.

The political divisions of South America are Spanish and Portuguese dominions, French and Dutch settlements, and unconquered countries.

SPANISH DOMINIONS.

NORTH.	CHIEF TOWNS.
New Grenada, or Terra Firma	Caracas, Carthagena, Panama.
MIDDLE.	
Peru and Chili - - -	Lima, Quito, Potosi, St. Jago.
SOUTH.	
Buenos Ayres, or Paraquay -	Assumption, Buenos Ayres.

PORTUGUESE DOMINIONS.

They consist of Brazil, and part of the vast tract called Amazonia, being 2,100 miles in length, and of nearly equal breadth. Of Amazonia, very little has been explored.

Of Brazil, the chief towns are, St. Sebastian, or Janeiro; and Bahia, or St. Salvador.

THE FRENCH SETTLEMENTS

are comparatively small. The chief town is Cayano, in the island Cayenne.

DUTCH SETTLEMENTS IN GUIANA.

	CHIEF TOWNS.
Surinam - - - -	Paramaribo, New Middleburg.

Demerara, Essequibo, and Berbice, are settlements at the northern extremity of this part of South America.

The unconquered regions are the internal parts of Terra Firma, Amazonia, Guiana, and Paraquay, with Patagonia, the southern extremity of South America.

ISLANDS OF AMERICA.

The islands of America are very numerous, large, and valuable.

The name, West Indies, is given to several groups of them, which lie in various directions, between North and South America. Of these, Cuba, Domingo or Hayti, Jamaica, and Porto Rico, in the Gulf of Mexico, are the largest. North of these, are the Bahamas; south, the Antilles, Caribbee, Leeward and Windward Islands, and Trinidad; westward the Spanish Leeward Islands.

The chief islands of North America are, Cape Breton, St. John's, Newfoundland, the Bermudas, or Sommer islands.

Of South America, the chief islands are the Gallipago isles, near the Equator; Juan Fernandez, Chiloe, Terra del Fuego, Statenland, the Falkland islands, Noronha, and Saremberg.

QUESTIONS.

Of what does America consist. and of what extent is that grand division of the earth? What are the rivers of North America? What are the lakes of North America? What are the political divisions of North America? What do the British possessions comprehend? What countries and cities constitute the United States? What are the Spanish dominions of North America? Which are the rivers of South America? What are the mountains of South America? What are the Spanish dominions and towns of South America? What are the Portuguese territories? Which are the French settlements? What are the Dutch settlements? What are the unconquered tracts of South America? What are the American islands?

CHAP. XXVII.

ASTRONOMICAL AND GEOGRAPHICAL INSTRUMENTS.

THE GLOBES.

The globes are two artificial spherical bodies, the one called the terrestrial, and the other, the celestial globes. The terrestrial globe represents the natural form of the earth; and upon its surface are depicted its oceans, seas, continents, islands, countries, and rivers. It is made moveable upon a spindle or axis, to imitate the movement which the earth is known to perform, once in every twenty-four hours, round its own axis, an imaginary line passing through the centre. This globe is moved from west to east, to imitate the real diurnal motion of the earth.

The celestial globe is formed in the same manner; but on its surface are represented the fixed stars, arranged under their respective constellations, and in their natural situations. It is moved from east to west, to imitate the apparent movement of the heavens, occasioned by the real movement of the earth. There are several circles and characters which are common to both globes; but some that belong to the celestial globe only.

The circles are, four large ones that divide the surface into equal portions or hemispheres; and four smaller, which divide it into unequal portions.

The equator, the ecliptic, the horizon, the meridian, are the four larger circles. The smaller circles are the two tropics, and the two polar circles.

The equator encompasses the globe at equal distance from the poles; that is, at ninety degrees; dividing it into a northern and a southern hemisphere: hence it is called the equator or equaller. Upon the celestial globe, it is named the equinoctial, because when the sun appears in it, the days are equal to the nights over the whole earth. By sailors, it is usually called the line. It is divided into 360 degrees, reckoning eastward from Aries. It is also generally numbered by a second row of figures, eastward and westward, to 180°; the figures nearest the equator proceeding westward, and those above them, eastward.

The ecliptic is a circle crossing the equator obliquely, its most distant points being only

twenty-three degrees and a half from it. This circle represents the sun's apparent path, the earth's real path, through the heavens, every year. In this circle, the sun appears to advance nearly one degree in twenty-four hours, and thirty degrees every month, till it has passed through the whole three hundred and sixty, in the space of 365 days, 6 hours, 56 minutes.

The horizon is the upper surface of the broad wooden circle, or frame, in which the globe stands. This circle determines the apparent rising and setting of the sun and stars, dividing the heavens into two hemispheres, which may be termed upper and lower, with regard to a spectator, at any place on the earth's surface.

Every place on the surface of the globe has its own horizon, the line where the sky seems to meet the land or water; so that, whenever we change our situation upon the earth, we change our horizon. By moving the globe till any given place be in the zenith, or point directly over head, the wooden horizon is made to represent truly the rational horizon of that place. The former is called the sensible horizon; the latter, the rational horizon.

The meridian is a brazen circle encompassing the globe at right angles to the horizon, dividing it into an eastern and western hemisphere. This circle of brass is graduated on one side.

Common meridians are semicircles, extending from pole to pole, and cutting the equator at right angles. These are called meridians, from th Latin word *meridies*, mid-day, because, when any one of these semicircles is brought by the

diurnal revolution of the earth, directly opposite the sun, it is noon or mid-day to all places under that meridian. Of these, twenty-four are usually described upon the globe. But as many meridians may be imagined as there are places on the earth's surface. Whenever we move towards the east or west, we change our meridian, the supposed semicircle passing over our heads from pole to pole.

To be able to determine accurately the situation of places on the earth's surface, two great circles have been fixed upon, from which to measure their distances; namely, the equator, the distance of any place from which, is measured northward or southward upon the graduated edge of the brazen meridian; and a certain meridian, called the first meridian, from which the distance is measured eastward or westward. Distance from the equator is called latitude. Distance from the first meridian is termed longitude. The meridian chosen by the English geographers, from which to measure eastern or western distance, is that which passes over the Observatory at Greenwich, near London, and which, also, nearly passes through the two first points of Aries and Libra.

The smaller circles are the tropics of Cancer and Capricorn: the first of which is twenty-three degrees and a half north of the equator; the latter, twenty-three degrees and a half south of the equator; the Arctic circle, twenty-three degrees and a half from the north pole; and the Antarctic circle, twenty-three degrees and a half

from the south pole. These smaller circles are parallel to the equator.

The tropics are so named from the Greek verb, signifying to turn; because, when the sun arrives at either of them, in his apparent annual course along the ecliptic, he appears to turn, and travel towards the equator.

Two small circles, usually described upon globes near the north and south poles, are called horary circles, because they are used to show the times of the rising and setting of the heavenly bodies, and of their continuance above the horizon. On some globes the equator is made the hour circle.

Points common to the terrestrial and the celestial globes, are the two poles, or extremities of the axis of the globe. The two equinoctial points, where the equator and the ecliptic intersect each other; the one, which is the first point of Aries, is called the vernal or spring equinox; the other, which is the first point of Libra, is called the autumnal equinox. The two solstitial points, the two points of the ecliptic which are at the greatest distance from the equator. The one, which is the first point of Cancer, is called the summer solstice; the other, the first point of Capricorn, is named the winter solstice. The term solstice is derived from the Latin words, signifying the sun, and to stand still; and is applied to them, because, when the sun arrives at either of those points, he appears to rise and set in exactly the same place for several days, and then returns towards the other.

The four cardinal points, north and south, east and west. These are marked on the rational horizon.

Upon the celestial glóbe, are certain circles and points, in addition to those which are common to it and the terrestrial globe.

The zodiac, a belt sixteen degrees broad, which goes round the globe, and in the middle of which runs the ecliptic. Within this circle are the fixed stars, over which the sun passes in his apparent annual course. They are arranged in twelve constellations or signs, which are called the twelve signs of the zodiac. These signs being marked upon the ecliptic, divide it into twelve equal parts, which correspond to the twelve months of the year, as follow :

Aries, the ram - - -	March.
Taurus, the bull - - -	April.
Gemini, the twins - -	May.
Cancer, the crab - - -	June.
Leo, the lion - - -	July.
Virgo, the virgin - - -	August.
Libra, the balance - -	September.
Scorpio, the scorpion - -	October.
Sagittarius, the archer - -	November.
Capricornus, the goat - -	December.
Aquarius, the waterman -	January.
Pisces, the fish - - -	February.

The sun appears to advance through one of these each month. The first six of these signs are called, in our northern hemisphere, the summer signs; the other six are called the winter signs.

The two colures are the two meridians which pass through the equinoctial points, and through the solstitial points: the one is called the equinoctial, and the other the solstitial colure.

The poles of the ecliptic are marked upon the celestial globe; and a number of semicircles, springing from them, are called circles of longitude; they serve to measure the distance of heavenly bodies from the ecliptic.

The poles of the horizon; of which that which is immediately over head, is called the zenith; that which is directly under foot, is called the nadir.

Azimuth, or vertical circles, are imaginary circles, meeting in the zenith and nadir, and cutting the horizon at right angles.

The quadrant of altitude is a thin slip of brass, having one of its sides graduated to ninety degrees. It is used for measuring the height of the heavenly bodies above the horizon, and for determining the distances and the bearings of places.

Upon the celestial globe, the latitude of a heavenly body is its distance from the ecliptic, measured upon a circle of longitude; and the longitude of a heavenly body is its distance from the first meridian, measured upon the ecliptic. The distance of the sun or a star from the equinoctial, is called its declination; and distance from the first meridian, measured upon the equator, is called right ascension.

By means of these globes, a number of curious, interesting, and instructive problems may be performed.

QUESTIONS.

What are the globes? Which way must the terrestrial, and which way must the celestial globe be turned, and what motions do those movements imitate? What are the large circles, common to both the globes? What are the smaller circles, common to the terrestrial and celestial globes? What points, and other marks, are common to both the globes? What circles and points are proper to the celestial globe? What is latitude on the celestial globe? What is the longitude of a heavenly body? What is declination? What is right ascension?

CHAP. XXVIII.

ASTRONOMICAL AND GEOGRAPHICAL INSTRUMENTS—continued.

THE ORRERY.

THE orrery is a machine contrived to show the motions of the planets round the sun, and of satellites, or secondary bodies, or moons, round their primary bodies, by means of balls of different sizes, moved by machinery. The first orrery made in Great Britain was constructed by Rowley for King George I. The excellent astronomer Ferguson, also, made an orrery which exhibited the movements of the sun, Mercury, Venus, the earth with her moon, and, occasionally, those of the superior planets, and of the moons of Jupiter and Saturn. Since his time these instruments are fabricated with great neatness and ingenuity, of various magnitudes.

The reason of this machine's being called by

the name Orrery, is, that one of the first of them known was made for an earl of Orrery, a very scientific man, and patron of the arts.

THE PLANETARIUM.

The planetarium is a machine, answering the same purposes as the orrery, contrived by an ingenious mathematical instrument-maker in London, of the names of Jones. By various machinery, the planetarium represents all the motions and phenomena of the planetary system. This machine is also made to represent the Ptolemaic system, and to exhibit, at the same time, a manifest confutation of it. It shows all the planets at once in motion about the sun, with the same respective velocities and periods of revolution which they have in the heavens, with the eclipses which they experience or occasion.

THE COMETARIUM.

The cometarium is a curious machine invented by Desaguliers. It shows the motion of a comet, or eccentric body, moving round the sun, describing equal areas in equal times; and is so contrived as to exhibit such a motion for any degrees of eccentricity.

THE TRAJECTORIUM LUNARE.

The trajectorium lunare is a machine which delineates the paths of the earth and the moon, showing what sort of curves they make in the etherial regions.

THE PENDULUM CLOCK.

The pendulum clock is an instrument contrived to show equal time in hours, minutes, and seconds. By hearing the beats of this pendulum the observer may count time by his ear, while his eye is employed in watching the motion of a heavenly body.

THE ASTRONOMICAL QUADRANT.

Astronomical quadrants are some of the most valuable of astronomical instruments. They are used for observing meridians, and other altitudes of the celestial bodies, and are either mural or portable.

The mural quadrant is in the form of a quarter of a circle, contained between two radii, at right angles to one another, and an arch equal to one fourth part of the circumference of a circle. It is fixed to the side of a wall, and the plane of it erected exactly in the plane of the meridian.

Tycho Brahe was the first person who contrived this mural arch or quadrant.

These instruments are usually made from five to eight feet radius.

The portable astronomical quadrant is an instrument of the greatest use to astronomers, as it may be carried to any part of the world, and put up for observation in an easy and accurate manner.

THE ASTRONOMICAL OR EQUATORIAL SECTOR.

This is an instrument for finding the difference, in right ascension and declination, between two

objects, the distance of which is too great to be observed by the micrometer.

THE TRANSIT INSTRUMENT.

This instrument is used for observing objects as they pass over the meridian. It consists of a telescope, fixed at right angles to a horizontal axis, which axis must be so supported that the line of sight of the telescope may move in the plane of the meridian.

THE MICROMETER.

The micrometer is an instrument, by which small angles, or the apparent magnitudes of objects viewed through telescopes or microscopes, are measured with great exactness. It effects this end by pieces of metal ground to a very fine edge; or fine hairs; or a net of silver wire, applied to the object glass of a telescope; or by specula; or by the light of a lamp.

THE TELESCOPE.

The telescope is an instrument that enlarges the visual angle subtended by a distant object, and thereby is said to magnify it, so as to render it visible to the eye of an observer. Thus it makes distant objects appear close to the eye.

The effect of the telescope depends upon this simple principle, namely, that objects appear larger in proportion to the angles which they subtend at the eye; and the result is the same, whether the pencils of rays by which objects be-

come visible to us come directly from the objects themselves, or from any place nearer to the eye, where they may have been converged, or brought together in a point, so as so form an image of the object. In fact, therefore, all that is effected by a telescope is, first, to make such an image of a distant object, by means of a lens, that is, a glass ground in a particular manner, or by a mirror; and then to give the eye some assistance for viewing that image as near as possible. This is done by means of an eye-glass, which so refracts the pencils of rays that they may afterwards be brought to their several foci by the humours of the eye. Such is the telescope which was first discovered and used by philosophers. The rays of light proceeding from the object itself, passing through glasses, were made to subtend larger angles at the eye than they would have done without such aid; and thus the object was magnified, and apparently brought nearer to the beholder. This effect of two lenses, or glasses, one concave and the other convex, placed at a proper distance from each other, appears to have been discovered by chance, towards the end of the sixteenth century. This discovery is attributed to a philosopher named Metius; to Lippershum, a spectacle maker at Middleburg; and to Jansen, another optician of the same place, A.D. 1590. Whichsoever of them first remarked the property that such a combination of glasses possesses, of showing distant objects, placed the glasses in tubes, and thus made the first telescope. The term telescope is combined from two Greek words, signifying distance and

the action of seeing. For many years after this discovery, no other telescope was imagined. Galileo and others improved it, and, by its assistance, made important discoveries concerning the heavenly bodies. These were called refracting telescopes, and they were obliged to be made of an unmanageable length, in order to increase their powers to any very great degree. To remedy this, was invented the reflecting telescope, which magnifies the reflected images of objects, and not the objects themselves. For the eye-glass of the common telescope, is substituted a metallic speculum or mirror of a parabolic figure, to receive the rays coming direct from the object observed, and to reflect them towards a smaller speculum of the same metal: this returns the image to an eye-glass placed behind the greater speculum, which, for that purpose, is perforated in the centre. This invention is attributed to Gregory of Aberdeen, and was published in 1663; but Sir Isaac Newton, and others since his time, have greatly improved the reflecting telescope; and Herschel seems to have brought to perfection this instrument, which has so wonderfully extended the sphere of human vision.

QUESTIONS.

What is the orrery, and whence does that instrument derive its name? What is the instrument called planetarium? What is the cometarium? The trajectorium lunare? The pendulum clock? What is the mural quadrant, and the portable quadrant? What is the equatorial sector? The transit instrument? The micrometer? By whom, and when, was the telescope invented? What does

that instrument effect? What is the construction of the refracting telescope? What is the nature of the reflecting telescope?

CHAP. XXIX.

NAVIGATION.

NAVIGATION is the art of conducting a ship from one place to another, and of steering its course over the waters of the ocean, in the safest, shortest, and most commodious way.

Historians represent this art to have been first cultivated by the Phœnicians; especially by the inhabitants of Tyre. Mount Lebanon and the neighbouring hills furnished them with abundance of excellent timber; of which taking advantage, they built numerous ships, and sent their merchant fleets, not only round the shores of the Mediterranean, but also through the straits of Gibralter into the vast Atlantic ocean, along the western coasts of Africa and Europe. The Carthagenians, Phœnician colonists, imbibed the spirit of the mother country, and paid particular attention to navigation. By means of their superior skill in this art, they long maintained successful opposition to the Romans, and attained, through commerce, to great wealth and power. Hanno, one of their admirals, is said to have circumnavigated Africa. From Phœnicia, upon the destruction of Tyre by Alexander the Great, the science of Navigation was transferred to Alexandria in Egypt, a city built by that

mighty conqueror, for the express purpose of serving as an emporium for eastern and western commerce. The Greeks, likewise, had, before that period, paid great attention to navigation, and had settled colonies on different parts of the coasts of the Mediterranean, and the Black sea. The fall of the Roman empire for a time extinguished this as well as the other sciences and arts.

Navigation revived in Italy, where the Venetians and the Genoese cultivated it to a high degree, to their own great profit. But till the invention of the compass, and its application to the purposes of navigation, in the year 1420, it must have been little better than mere coasting; that is, directing the course of vessels by headlands, promontories, and capes, and by observations made upon certain of the fixed stars. This is called navigation common.

But navigation has been vastly improved in modern times, both with regard to the form of the vessels, and with regard to the methods of working them. The use of oars is now almost entirely superseded by the vast improvements made in the formation of sails and rigging; so that ships not only sail much faster than in ancient times, but can also tack, or be turned, in every different direction. The adventurous mariner now finds his way across the trackless ocean to the most distant regions of the globe, and can determine exactly the path his vessel takes, and what are her successive situations with respect to other parts of the earth's surface. This art connects the remotest countries and nations;

thus increasing the knowledge and the comforts of man.

In its present advanced state, this science is termed navigation proper.

The theory of Navigation rests upon the following circumstances and principles.

The motion of a ship in the water depends upon the action of the wind upon the sails, regulated by the direction of the helm. The guidance of a ship's motion depends upon the position of her sails with regard to the wind, combined with the action of the rudder. The most natural direction of a vessel is when she runs immediately before the wind; for the sails are then so placed, as to be at right angles thereto. But on account of the variable nature of the winds, and of the situation of intended ports, or of intermediate headlands or islands, this cannot be always the case. When, therefore, the wind is not favourable, the sails are so placed as to make an oblique angle both with the direction of the ship, and with the wind; and the sails, together with the rudder, must be managed in such a manner that the direction of the ship may make an acute angle with that of the wind, and thus the vessel, gaining some way, by each different tack, may finally reach the port for which she was destined.

In many parts of the ocean, there are currents which run with considerable velocity in certain directions, and which may carry a ship greatly out of her course, and this must occasion an error in the reckoning of the navigator.

Another source of error in reckoning the

course of a ship, proceeds from the variations of the compass. There are few parts of the world where the needle points exactly north; and even in those parts where the variation is known, it is subject to considerable alterations. By these means, the course of a ship may be miscalculated; for, as the sailors have no other standard to direct them than the compass, if the needle, instead of pointing due north, should point north-east, a prodigious error would be occasioned during the course of a long voyage, and the vessel would not nearly approach the port for which she was bound.

The only method by which such errors can be avoided, is to observe the sun's amplitude and azimuth as frequently as possible; by which the variations of the compass will be perceived, and the proper allowances can then be made for errors in the course which may have taken place.

Errors may, likewise, arise in a ship's reckoning, especially when she is sailing in high latitudes, from the spheroidal figure of the earth. For as the polar diameter of the globe is shorter than the equatorial diameter, it follows thence that the farther we remove from the equator, the longer are the degrees of latitude.

It is of consequence to navigators, in a long voyage, to take the nearest way to port; but to do this is no small difficulty. The shortest distance between any two points on the surface of a sphere, is measured by an arch of a great circle intercepted between them. This is not an easy task to be performed; since there are no

fixed marks by which it can be readily known whether the ship be sailing in the direction of one of the great circles, or not. For this reason, the sailors generally chuse to direct the vessel's course by the rhumbs, or, the bearing of the place to which they wish to go, by the compass. These bearings do not point out the shortest distance between places; because, on a globe, the rhumbs are spirals, and not arches of great circles. However, when places lie immediately under the equator, or exactly under the same meridian, the rhumb, in that case, coincides with the arch of a great circle, and of consequence shows the nearest way. The sailing on the arch of a great circle, is called great circle sailing; and its cases all depend on the solution of problems in spherical trigonometry.

The art of navigation depends upon astronomical and mathematical principles. The places of the sun, and fixed stars, are deduced from observation and calculation, and arranged in tables, for the purpose of ascertaining the latitude and longitude of the ship, and the variations of the compass. The problems in the various sailings are resolved either by trigonometrical calculations, or by tables, or rules, formed by the assistance of trigonometry. The necessary tables are constructed by means of mathematics; and rules are established for performing the more difficult parts of navigation.

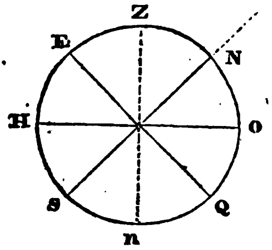
The situation of a place on the surface of the earth, is estimated by its distance from two imaginary lines intersecting each other at right angles; the one of these is the equator, and

the other the first meridian. The situation of the equator is fixed; but that of the first meridian is arbitrary, and, therefore, different nations assume different first meridians. The British astronomers assume as their first meridian, that which passes over the observatory at Greenwich. Latitude is the distance of any place or ship from the equator north or south; reckoned on a meridian in degrees and parts of a degree; the longitude of any place or vessel is that portion of the equator contained between the first meridian and the meridian of the given place, and is either east or west, according as it is in the eastern or western hemisphere, respectively to the first meridian.

Navigation, therefore, teaches certain methods of finding the latitude and longitude of a vessel, and, by this means, of discovering in what part of the ocean the vessel is. The compass will direct the mariner in his course, and show him towards what quarter he is steering, but it discovers neither the coasts he has left behind, nor those which he is endeavouring to find. In this extremity he applies to the heavens. The same stars which he observed when in his native country, he still beholds, and they become his guides. Being fixed in their relative stations, their situations are known, and, from this property, rules have been framed which enable him to find his latitude. But as many places have the same latitude, this only informs him that he is somewhere in a certain circle which is parallel to the equator. To find exactly in what point of this circle he is, he must also find

the difference of longitude, and determine the meridian that cuts the parallel in the place occupied by his vessel.

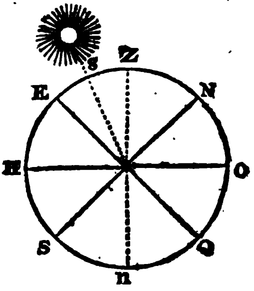
The first method of discovering the latitude, is to find the height of the pole star. For as this point is immoveable in the heavens, and is found to appear elevated or depressed, according to a nearer or farther situation from the equator, this becomes a criterion for judging of distance from that circle. If the pole star appear nearer to the horizon than it did at the place whence the ship sailed, exactly in the proportion in which it so appears must the ship have proceeded southwards from that place towards the equator. On the contrary, if the pole star be higher in the heavens nearer to the zenith, then it is plain that the vessel must have advanced northwards from the place of departure towards the pole. Thus



Let NS be the axis of the earth, EQ the equator, and Z the zenith, or place of observation. Then since ZO, the distance of the zenith from the horizon, is ninety degrees; and

NE, the distance of the pole from the equator, is also ninety degrees; the arc OZ will consequently be equal to the arc NE; and if the arc NZ, which is common to them both, be taken away, the remainder ON, will be equal to the remainder ZE: but ON, is the height of the pole above the horizon, and ZE is the latitude of the place, or its distance from the equator; and, therefore, if the height of the pole above the horizon be taken by means of a quadrant, it will evidently give the latitude of the place where the observation is made.

The latitude may, likewise, be found, and found more accurately, by taking the altitude of the sun, or of a star, when it is upon the meridian. Thus



Suppose that a spectator at Z sees the sun at noon, over the point S, and finds with a quadrant, the meridian altitude, HS, then if this altitude be taken from HZ, or ninety degrees,

it will give the zenith distance, ZS, and the zenith distance ZS, being added to the declination of the sun, SE will be the latitude of the place required, that is, of that spot on the earth's surface where the vessel then is.

The latitude is thus easily and pretty accurately ascertained; but to determine the longitude is a business of the utmost difficulty. But it is so intimately connected with the prosperity of commerce, that, by an act of parliament passed in the year 1714, the British parliament offered the reward of £20,000 to any person who should discover a method for finding the longitude within thirty miles, or half a degree of a great circle.

The first and simplest method of finding the longitude, is to find the direction in which the the ship is sailing by means of the compass, and to measure the distance passed over, by the log; then the latitude and longitude of the ship's situation, may be determined by examining the chart.

Thus. Suppose a vessel departs from a place whose latitude is 57° 20′ north, and longitude 16° east, and that it has sailed east south east, one hundred leagues; then, in order to determine the situation of the place at which it is arrived, take a map or chart, and find the place whence the ship departed, and draw a right line, making the same angle with the meridian, east south east, as was shown by the compass; on this line set off the distance one hundred leagues taken from the scale, and that point will represent, on the chart, the situation of the ship.

But this method is liable to many errors; a much better method of ascertaining the longitude, is by means of the Chronometer, an instrument for measuring time.

As places differ in longitude, the clocks and watches of those places, supposing them to be well regulated, will show different hours at the same moment of absolute time; a difference of 15° of longitude always producing a difference of one hour in the time as shown by those useful machines. If, therefore, a watch or timepiece, could be made to go so regularly as to show, in any part of the world to which it might be carried, the exact time at London, by its means the longitude might be determined. For that purpose it would only be necessary to find when the sun came to the meridian of the situation of the ship, or was due south; and as that would determine it to be twelve at noon, the time thus found, being compared with the time shown by the watch, and the difference turned into degrees and minutes, would give the longitude required. Supposing the situation of the vessel to be on the coast of some land unknown, but which it was requisite to know. Then, suppose the moment when it is noon to be determined in the same manner as before, and the watch shows the London time to be five hours seven minutes and two seconds in the afternoon: by allowing fifteen degrees to an hour, it is found that the longitude of the vessel is 76° 45½′ west of London. By this means, it is ascertained under what meridian the vessel is; but still it is un-

certain under what precise point of that meridian she lies. To discover this, by observing the altitude of the sun at noon, her latitude is found to be 18° north; then by looking into the map or chart, the place having 76° 45½′ west longitude, and 18° north latitude, is Port Royal in Jamaica.

Thus might the longitude be at all times discovered, could time keepers be made perfectly accurate. But the irregular motions of a ship at sea, and the different temperature of the atmosphere in different climates, occasion errors which seem to admit of no adequate remedy. Harrison, an excellent artist, constructed a chronometer, which approached near to the desired perfection; in consequence of which, the half of the reward offered by parliament was granted to him, and some time after, upon his explaining the principles of his time keepers, so as to enable others to make them with the same accuracy, he received the remaining moiety of the promised recompense, for discovering the best method of determining the longitude.

The eclipses of the moon afford another method of finding the longitude of places; as do, likewise, eclipses of the sun, and occultations of the fixed stars; and the eclipses of Jupiter's satellites: at present this last method seems to be the most generally approved of.

As the tides depend upon the joint actions of the sun and the moon, and, therefore, upon the distance of these objects from the earth, and from each other; and, as in the method generally employed to find the time of high water,

whether by the mean time of new moon or by epacts, or tables deduced therefrom, the moon is supposed to be the sole agent, and to have a uniform motion in the periphery of a circle, whose centre is that of the earth; that method cannot be accurate because founded upon inaccurate principles; and, indeed, its error sometimes amounts to more than two hours. This method is, therefore rejected by navigators, and another adopted which makes the error seldom to exceed a few minutes. This operation is effected by two problems. The first problem is, to reduce the times of the moon's phases, as given in the nautical almanac, to the meridian of a known place.

Rule. To the time of the proposed phase, as given in the nautical almanac, apply the longitude of the place, in time, by addition or subtraction, according as it is east or west, and it will give the time of the phase at the given place.

Problem 2. To find the time of high water at a known place.

Rule. In the nautical almanac, seek, in the given month, or in that immediately preceding or following it, for the time of that phase, which happens nearest to the given day. Reduce the time of this phase to the meridian of the given place by the preceding problem, and take the difference between the reduced time and the noon of the given day. Find the equation answering to this difference in the proper table; which, applied to the time of high water, on the day of new or full moon at the given

place, as the table directs, will give the approximate time of high water in the afternoon.

Then, take the interval between the reduced time of the phase and the approximate time of high water; find the corresponding equation; which applied as before to the syzigy time of water will give the time of the afternoon high water. If the time of the morning high water is required, increase the last interval by twelve hours, if the given day fall before the phase; or diminish it by twelve hours, when it falls after that phase. And the equation to this time applied to the syzigy time, gives the morning time of high water.

The method commonly used at sea to find the distance sailed over in a given time, is by means of a log-line and half-minute glass. The interval between each knot made upon that line, called the log line, ought to be fifty feet in order to adapt it to a glass which runs thirty seconds. But though the line and glass be at any time perfectly adjusted to each other; yet as the line shrinks after having been wetted, and as the weather has a considerable effect upon the glass, it is, therefore, necessary to examine them from time to time, and the distance given by them must be corrected accordingly. For doing this, and finding the true distance sailed over, rules are laid down.

Problem 1. The distance sailed by the log, and the seconds run by the glass being given, to find the true distance, the line being supposed right,

Rule. Multiply the distance given by the

log, by thirty; and divide the product by the seconds run by the glass; the quotient will be the true distance.

Problem 2. Given the distance sailed by the log, and the measured interval between two adjacent knots on the line; to find the true distance, the glass running exactly thirty seconds,

Rule. Multiply twice the distance sailed, by the measured length of a knot; point off two figures to the right, and the remainder will be the true distance.

Problem 3. Given the length of a knot, the number of seconds run by the glass, in half a minute; and the distance sailed by the log; to find the true distance.

Rule. Multiply the distance sailed by the log, by six times the measured length of a knot, and divide the product by the seconds run by the glass; the quotient, pointing off one figure to the right, will be the true distance.

PLANE SAILING.

Plane sailing is the art of navigating a ship upon principles deduced from the notion of the earth's being an extended plane. Upon this supposition the meridians are regarded as parallel right lines. The parallels of latitude are at right angles to the meridians; the lengths of the degrees on the meridians, the equator, and the parallels of latitude, are every where equal, and the degrees of longitude are reckoned on the parallels of latitude as well as on the equator. In plane sailing, four circumstances are prin-

cipally concerned; namely, course, distance, difference of latitude, and departure.

The course is the angle contained between the meridian and the line described by the ship; and is usually expressed in points of the compass.

The distance, is the number of miles a ship has sailed on a direct course, in a given time.

Difference of latitude is the portion of a meridian contained between the parallels of latitude sailed from and come to; and is reckoned either north or south, according as the course is in the northern, or the southern hemisphere.

The departure, is the distance of the ship from the meridian of the place she left reckoned on a parallel of latitude. In this sailing, the departure and difference of longitude are esteemed equal.

TRAVERSE SAILING.

If a ship sail upon two or more courses in a given time, the irregular track she describes is called a traverse; and to resolve a traverse, is the method of reducing these several courses, and the distances run, into a single course and distance. The method chiefly used for this purpose, is called inspection, and is performed by means of a table; in which are arranged, in separate columns, the courses, the distances, differences of latitude, and departure.

PARALLEL SAILING.

The figure of the earth being spherical, the meridians gradually approach one another, and

meet at the poles. The meridian distance, answering to the same difference of longitude, will, therefore, be variable with the latitude of the parallel upon which it is reckoned; and the same difference of longitude will not answer to a given meridian distance, when reckoned upon different parallels.

Parallel sailing, is the method of finding the distance between two places lying in the same parallel, whose longitudes are known: or to find the difference of longitude answering to a given distance run in an east or west direction. This sailing is particularly useful in making low, or small islands.

MIDDLE LATITUDE SAILING.

The earth being a sphere, the meridians meet at the poles; and since a rhumb line makes equal angles with every meridian, the line which a ship describes is, therefore, that kind of curve called a spiral. To resolve and reduce this is taught by middle latitude sailing.

MERCATOR'S SAILING.

The difference of longitude made upon an oblique rhumb cannot be exactly determined by using the middle latitude sailing. In mercator's sailing, the difference of longitude is very easily found, and the several problems of sailing resolved with the utmost accuracy, by the aid of a chart, or equivalent tables, in which the meridians are straight lines parallel to one another; and the degrees of latitude, which, at the equator, are equal to those of longitude,

increase with the distance of the parallel from the equator. The parts of the meridian, thus increased, are called meridianal parts.

CURRENT SAILING.

The preceding methods of navigation, are founded upon the assumption that the water has no motion. And these may answer tolerably well in those parts, where the ebbings and flowings are regular, as then the effect of the tide will be nearly counterbalanced. But in places where there is a constant current, or setting of the sea towards the same point, an allowance for the change of the ship's place, arising from its influence, must be made. The method of resolving those problems, in which, the effect of a current or heave of the sea is taken into consideration, is called, current sailing.

Oblique sailing is the application of oblique angled plane triangles to the solution of problems at sea. This branch of navigation is peculiarly useful in coasting, and in the surveying of shores and harbours.

Windward sailing is, when a ship, is obliged by a contrary wind, to sail on different tacks in order to gain her intended port, and the object of this part of the science of navigation is to find the proper course, and distance to be run on each tack. For the accomplishment of this, there are several problems and operations.

QUESTIONS.

What is navigation? Among what nations of antiquity was navigation most cultivated? Among what modern nations has navigation been most cultivated? What is na-

vigation common? What is navigation proper? Upon what principles and sciences does navigation depend? Upon what combining causes does a ship's movement depend? To what errors is the science of navigation exposed? What are the methods of finding the latitude of a ship? What are the methods of finding a ship's longitude? What is plane sailing? What is traverse sailing? What is parallel sailing? What is middle latitude sailing? What is mercator's sailing? What is current sailing? What is oblique sailing? What is windward sailing?

CHAP. XXX.

INSTRUMENTS USED FOR ACCOMPLISHING THE PURPOSES OF NAVIGATION.

Of these, the principal are,

The compass, by which pilots ascertain and direct the course of ships. This consists of a circular brass box, which contains a paper card, marked with the thirty-two points into which the various directions of the winds are usually divided, fixed on a magnetic needle that always turns towards the north pole, excepting a small declination variable at different places.

The needle, together with the card, turns on an upright pin fixed in the centre of the box. In the centre of the needle is fixed a brass conical socket or cap, whereby the card, hanging on the pin, turns freely round the centre.

The top of the box is covered with glass, that the motion of the card may not be disturbed by the wind. The whole of this apparatus is in-

closed in another box of wood, where it is suspended by brass hoops, to preserve the card in a horizontal posture.

The compass box must be so placed in the ship, that the middle section of the box, parallel to its sides, may be parallel to the middle section of the vessel along its keel.

The invention of the compass is usually ascribed to Flavio da Melfi, or Flavio Gioia, a Neapolitan, about the year 1302. Others assert that the knowledge of this most useful instrument, was brought from China by the famous Venetian traveller, Marco Paulo, in 1260. Certain it is, that at first, the compass was fixed on a small piece of cork, which floated in water instead of being suspended on a pivot; the very practice which the Chinese still retain. This instrument has been greatly improved by Dr. Knight and Mr. Smeaton.

THE LOG.

The log is a small piece of wood, of a triangular form generally, about a quarter of an inch thick, and five or six inches from the angular point to the circumference. It is balanced by a thin plate of lead, so as to float perpendicularly in the water. To this is fastened a cord, or line, about one hundred and fifty fathoms long, one end of which is affixed to a reel in the gallery of the ship. This line, from the distance of about ten, twelve or fifteen fathoms off the log, has certain knots or divisions, which ought to be fifty feet from each other. The length of each knot is the same part of a sea mile, as half a mi-

nute is of an hour. A nautical mile is computed at 6120 feet.

The use of the log and line is to keep account, and make an estimate of the ship's way, or distance run. This is done by observing the length of line unwound in half a minute of time, told by a half minute glass; for so many knots as run out in that time, so many miles the ship sails in an hour. Thus, if there be four knots veered out in half a minute, the vessel is computed to sail at the rate of four miles an hour. To whom the honour of this invention is due, is unknown. To heave the log, as it is called, it is thrown into the water on the lee side of the ship, and let run till it comes without the eddy of the ship's wake. Then one person, holding a half minute glass, turns it up just as the first knot, or the mark from which the knots begin to be reckoned, turns off the reel, or passes over the stern. As soon as the glass is out, the reel is stopped, and the knots which are run off are reckoned, and the parts estimated.

CHARTS.

The charts usually employed in the practice of navigation, are of two kinds; plane charts, and Mercator's charts. The plane chart is a representation of some part of the surface of the earth, in which the meridians are supposed parallel to each other; the parallels of latitude at equal distances, and, consequently, the degrees of longitude and latitude every where equal to each other.

Mercator's chart has the meridians straight lines,

parallel to each other, and equidistant. The parallels are also straight lines, and parallel to each other. But the distance between them increases from the equator towards either pole, in the ratio of a secant of the latitude to the radius.

HADLEY'S QUADRANT.

This is the chief instrument used at present, for observing altitudes at sea. The form of this instrument is an octagonal sector of a circle, and, consequently, contains forty-five degrees. It consists of the frame; an arch, or limb; an index and subdividing scale; an index glass; a fore horizon glass; a back horizon glass; coloured, or dark glasses; and vanes, or sights. This machine is very useful in navigation. By it the most accurate observations may be taken. It is easy to manage, at the mast head as well as on deck; by which its sphere of observation is greatly extended. It is formed upon a principle which originated with the celebrated Dr. Hooke, and was completed by Sir Isaac Newton; though it has received its name from Mr. Hadley, who first published an account of it.

THE SEXTANT.

The sextant is an instrument for the purpose of measuring, with accuracy, the angular distance between the sun and the moon, or between the moon and a fixed star, in order to ascertain the longitude by lunar observations. It is, therefore, constructed more carefully than the quadrant, and is more complicated. It has an arch, divided into 120 degrees; each degree is divided into three parts; each of those parts, therefore,

contains twenty minutes, which are subdivided into half minutes; an horizon glass; an index glass; and several coloured glasses. The sextant is furnished, likewise, with a plain tube without glasses; two telescopes; mirrors, and a magnifying glass.

THE CIRCULAR INSTRUMENT OF REFLECTION.

This instrument was made to correct the errors to which the sextant is liable; especially an error which arises from the inaccuracy of the division on the limb. It consists of a circular ring or limb of metal, connected with a perforated central plate by six radii, and divided into 720 degrees; two moveable indices; two mirrors; a telescope; and coloured glasses.

THE SHIP'S JOURNAL.

A journal is a regular and exact register of all the various transactions that take place on board a ship, whether at sea or land; and more particularly an account of the ship's way; whence her place at noon, or at any other time, may be justly ascertained. That part of the account which is kept at sea, is called sea-work; and the remarks inserted in the journal during the time the ship is in port, is called harbour-work.

At sea, the day begins at noon, and ends at the noon of the following day. The first twelve hours, namely those contained between noon and midnight, are denoted by the letters P.M. or post meridiem, after midday, and the other twelve, that is the hours which elapse between midnight and noon, are denoted by A. M. ante meridiem, before midday. So that the work of

a day marked, Tuesday, April 24, began on Monday, April 23, at noon, and ended on that Tuesday, at noon.

The days of the week are usually represented by astronomical characters.

☉ Sunday. ☽ Monday. ♂ Tuesday.
☿ Wednesday. ♃ Thursday. ♀ Friday.
♄ Saturday.

The several courses and distances sailed in the course of twenty-four hours, that is between noon and noon, and whatever remarks are deemed worthy of notice, are written with chalk on a board painted black, called the log-board. This is usually divided into six columns. The first on the left hand, contains the hours from the noon of one day to that of the next; the second and third, the knots and parts of knots sailed every hour, or every two hours, according as the log is marked; the fourth column contains the courses steered; the fifth, the winds; and the sixth, the various remarks and phenomena. The log-board is transcribed every day, at noon, into the log-book, which is divided and ruled after the same manner. The settling and drift of currents, and the heave of the sea, are marked down likewise. The computation made from the several courses, and their corresponding distances, is called a day's work; and the ship's place, as deduced from that work, is called her place by account, or dead reckoning.

QUESTIONS.

What are the principal instruments used for the purposes of navigation? What is the compass? Hadley's quadrant? The sextant? What is the log? What is the plane chart? What is Mercator's chart? What is the circular instrument of reflection? How is a ship's journal kept?

CHAP. XXXI.

GEOLOGY OR GEOGNOSY.

Geology, or as it has been likewise called, geognosy, treats of the internal structure of the earth, as far as human labour and skill have been able to penetrate below its surface. Those names are compounded of Greek words signifying, discourse concerning the earth, or knowledge of the earth. Geology may be considered as descriptive, or speculative.

Descriptive geology gives a general account of the materials of which the globe is composed, and of their arrangement.

Speculative Geology is confined to what may be called a theory of the earth; or an attempt to explain the manner in which its structure and arrangement have been produced, and the changes which have taken place in the disposition of the component parts of the earth.

The materials of which the general mass of the earth is composed, are variously distributed in different parts. In some places they exist in irregular masses, or blocks, either buried below the surface, or elevated at differerent heights

above it. These materials are, however, generally found arranged with considerable regularity; those of the same kind being collected in extensive masses, lying in layers, or strata, as they are called, above or below a similar collection of another kind, or these alternated with each other to a considerable depth. These strata are found sometimes parallel to the horizon, at other times perpendicular to the horizon; but more commonly, they are inclined obliquely towards the horizon. The uppermost stratum is, in most parts, covered to a certain depth with mould, which has evidently been formed from the decomposition of organized substances. Sometimes the strata are continued in regular arrangement, preserving the same inclination to a great extent; but more commonly they appear in separated parcels, as if broken asunder by violence. These clefts, or separations, have generally a vertical direction, and are filled with various heterogeneous matters.

When these fissures are filled up with broken fragments, it frequently happens that they become beds of brooks or rivers. When these cavities are filled with solid stony matter, they are called dykes; but if they be filled with mineral or metallic substances, they are then styled veins. Sometimes these chasms in the strata contain nothing but water.

These materials, constituting the general mass of our planet, as far as known to mankind, are distributed, by modern geologists, into two classes; one, consisting of those substances which are found more or less connected with

the remains of organized bodies, such as the bones, teeth, and shells of animals, the trunks of trees, and various parts of vegetables; the other, comprehending those in the substance of which such organic remains are never found. The latter of these are supposed to have been formed first, and are, therefore, called primary substances; while the former are termed secondary substances.

The primitive substances are as follows:

1. Granite. This name has been long given to all stones which are composed of an aggregate of other stones, distributed in it in such a manner as that each of them appears in a separate state. Granite is the basis of all the other strata; is found in the highest and lowest parts of the earth, and commonly exists in large blocks. This is the case in most mountains, especially in those which have high pointed summits. Of granite, most of the British mountains are composed.

2. Gneiss. A substance sometimes incorporated with masses of granite, but generally found reposing on granite. In Gneiss are often existing metallic ores of various kinds; and some whole mountains are composed of it.

3. Micaceous Schist. This substance is composed of nearly the same materials as granite and gneiss, and is very abundant in most rocks and mountains. In this, metallic ores are likewise found.

4. Quartz. In this substance no metals are found, though it sometimes contains petroleum, or rock oil. Whole mountains are composed of

quartz; particularly a mountain called Kultuc, at the south-east end of Lake Baikal, which consists entirely of milk white quartz: Flinzberg, in Lusatia; and the mountains of Ross and Inverness, which, at a distance, exhibit the appearance of being covered with snow.

5. Argillaceous Schist, or clay-slate. Of this the famous mountains of Potosi, in South America, consist, and many others; but it is not very common in Britain.

6. Jasper. Primitive jasper is always opaque, and is commonly found embedded in other stony substances. Its colour varies from red to green; and frequently consists of alternate stripes of those colours, sometimes perfectly distinct, and sometimes blending together. Striped jasper is so abundant in some parts of the earth, as to form the chief material of mountains, mixed with fragments of granite Hills of red jasper, and of green jasper, are seen in some countries.

7. Hornstone. A substance found in large, thick masses, and constituting the principal component parts of some mountains.

8. Pitchstone. A stony matter, found in large masses of an irregular form, and of different colours, having sometimes the appearance of rosin, and sometimes of enamel of imperfectly transparent glass. It is never crystallized.

9. Horneblende. A substance often found mingled with quartz, and sometimes existing separately, as in Siberia, where there are mountains of black horneblende.

10. Serpentine. A stone similar to the pre-

ceding, with respect to its ingredients. It is generally of a greenish ground, marked with white yellow, brown, or reddish spots, so as to bear some resemblance to the skin of a snake. From this circumstance it derives its name. Rocks and hills of this substance are found in Siberia; near the White Sea; in Germany; on the coast of Cornwall; and in the vicinity of Genoa.

11. Porphyry. This stone generally consists of the same materials as granite, but in different proportions, and of a very different appearance. It is found in the greatest abundance in tropical countries.

12. Pudding stone and Breccia. These are stones composed of fragments of other stones, cemented by hardened clay, and are found in many parts of the world in great abundance.

13. Syenite. A greenish, granulated substance, deriving its name from Syene, in Upper Egypt, where it was raised in great quantities, and sent to Rome for public edifices.

14. Primitive Limestone. This stone is of a granular structure, and of a whitish grey colour, though sometimes of a dark iron grey, or of a reddish brown. There is in Spain an extraordinary mountain of this substance, named Filabres. It is white; three miles in circumference, and two thousand feet high, without any mixture of other earths or stones, and having scarcely any fissure.

15. Primitive Trap. Trap is a name given by Swedish mineralogists, to distinguish certain stones which are of a compact texture, and a

dark colour, composing part of several mountains. But many rocks have received the common name of trap.

Primitive trap frequently contains metals, and is found in vast strata, in the midst of gneiss, granite, and micaceous schist. Fifteen other substances are enumerated by geologists; the most important of which are gypsum, or plaster-stone. Of this there are six varieties.

Chalk. This substance, so well known, is not always white, but is frequently found coloured. It is disposed in horizontal beds, often many yards thick, and which always repose on layers of other calcareous stones of harder structure.

Clay. This substance is found in various states with respect to hardness or solidity, from the soft ductile clay of the potter and pipe maker to the perfect slate.

Marl. A substance chiefly composed of sand, clay, and calcareous matter, which is found in many places, and forms one of the most valuable natural manures used in agriculture.

Rock Salt. This is the purest salt found in nature, being less impregnated with extraneous matters than what is procured from sea-water. It is hard; commonly transparent; generally white; but sometimes yellow, blue, red, or violet. This salt forms horizontal beds or banks, of immense extent, and often very deep in the earth.

Coal. This substance, which is of such vast utility to man, is commonly solid, black, very dry, and considerably hard, and combustible, existing in various forms and species. It has been used for fuel in this country, for many

centuries. Coal lies in strata or beds, like other mineral substances, frequently of very great extent, and in various directions. The beds in which coal is disposed, usually have their extremities near the surface of the ground, from which they bend obliquely downwards, the middle part of the bed being nearly horizontal. Coal, in a greater or less quantity, has been found in most countries, and probably exists in all.

Those organic remains of vegetable and animal matter which are found below the surface of the earth, mixed with those stony matters which are properly the component parts of the earth, are generally called fossils, or extraneous fossils. If they have entirely lost all traces of animal or vegetable matter, and have assumed a stony, earthy nature, they are then styled petrifactions. Almost every part of vegetables, and even whole trees, are found in a fossil state, below the surface of the earth, particularly in bogs and mosses. These, sometimes, retain much of their vegetable nature, but are more commonly impregnated with bitumen, or completely petrified. Fossils of animal matters, are still more common than those of vegetables. Shells and bones are found in almost every bed of limestone, and in all countries, at the bottom of the deepest valleys, and on the summits of many high mountains. Entire skeletons of very large animals have been discovered in a fossil state. In the plains of Siberia, have been found, buried at different depths, skeletons of elephants, and bones of the hippopotamus, and of still larger animals, whose species are supposed to have been long extinct.

QUESTIONS.

What is geology, and into what branches is this science divided? How are the materials of which the general mass of the earth is composed, distributed? How are these materials classed by modern geologists? What are the principal primitive substances? What are fossils and petrifactions? What are vegetable fossils? What are animal fossils?

CHAP. XXXII.

THEORIES OF THE EARTH.

THE theories which now divide scientific men are those of Hutton and of Werner.

THEORY OF HUTTON.—The leading principles of the Huttonian theory, are, first, that the greater part of the bodies which compose the exterior crust of our globe, bear the marks of being formed of the materials of mineral and organized bodies, the spoils or wrecks of an older world. Secondly, that the present rocks, excepting such as are not stratified, have all existed in the form of loose materials at the bottom of the sea, and must have been consolidated and converted into stone, by virtue of some powerful and general agent; which agent is subterraneous heat. Thirdly, that the stratified rocks have been raised by the action of some expansive force placed under them. This force, which has burst in pieces the solid pavement on which the ocean rests, and has raised up rocks from the bottom of the sea, into mountains fifteen thousand feet above its surface, is supposed to

be heat. Fourthly, that this force, heat, melted those mineral substances which are found injected into the chasms existing in the various strata of materials, of which the earth's body is composed. Fifthly, this theory states, that all the mineral bodies thus raised into the atmosphere, are going to decay; that from the shore of the sea, to the summit of the mountain, from the softest clay, to the hardest quartz, all are wasting and undergoing a separation of their parts. The bodies thus resolved into their elements, whether chemical, or mechanical, are carried down, by the rivers, to the sea, and are there deposited.

THE THEORY OF WERNER.—The Wernerian theory assumes, that the exterior part of the globe has been entirely dissolved by the waters which surrounded it; and that from this solution, certain chemical precipitations took place, which have formed that crust, or surface of the earth, which we now see. It supposes that these chemical precipitates did not form a regular surface, but that they collected here and there, so as to form the primitive mountains; that after the retreat of the waters, these elevated parts were first discovered; that being exposed to the destructive action of the elements, and the shock of tides and torrents, the valleys were hollowed out, and the mountains acquired nearly the form in which we now see them.

Werner imagines six of these precipitations or formations to have taken place; four of which he names universal formations, their products being found over the whole globe; the other two,

he calls partial, their products being found only in particular parts. These formations he has arranged according to the order in which he conceives them to have been produced; beginning with that which lies next to the solid nucleus of the earth, and which may, therefore, be conceived to be the oldest; and ending with the most superficial, which is considered as the newest formation. This theory is considered as an improvement upon that which is called the Neptunean; because it explains geological appearances by the action of water, in opposition to what is called the Vulcanean theory, because it attributes these appearances to the action of heat.

QUESTIONS.

What are the most esteemed theories concerning the formation of the earth? What is Hutton's theory? Werner's? Which is the Neptunian, and which the Vulcanian theory?

CHAP. XXXIII.

EARTHQUAKES AND VOLCANOES.

An earthquake is a sudden concussion, or shaking, of some part or other of the earth, generally accompanied by unusual noises, such as rumbling, or rolling sounds, or explosions, as of artillery; and by various effects; such as the emission of flames, water, or vapours. It agitates the ground in different degrees, from slight shocks to tremendous convulsions, overthrowing edifices, rocks, mountains, and very

extensive tracts of land. Of all the phenomena of nature, none so justly excites terror as the earthquake; as its unlimited, sudden, and dreadful effects leave no certain remedy, and no refuge of safety.

Earthquakes have been felt in most countries of the world. There are, however, particular places which seem to be more subject to this dreadful calamity than others; but this does not seem to depend on any local circumstances, with regard to particular regions of the earth. In general, earthquakes are more frequent within the tropics; yet there are regions within the torrid zone, which are more rarely visited by these commotions, than some of the more temperate, or even colder regions of the earth. In the islands of the West Indies, and in some parts of the American continent which lie between the tropics, the earthquake is experienced more often than in most other parts of the earth. But more desolating effects have been produced thereby on the northern shores of the Mediterranean, in Portugal, Sicily, and Italy.

Earthquakes are more frequent in volcanic countries than any others. Where a volcano exists, and when it has ceased to throw out flame and smoke for any long period, shocks of earthquakes begin to be dreaded. Earthquakes are often preceded by long droughts, and by various electrical appearances, such as the Aurora Borealis. Before the shock comes on, the waters of the ocean appear to be unusually agitated, without the operation of wind or any perceptible cause. Fountains and springs are also greatly

disturbed, and their waters become muddy. The air is often unnaturally calm and serene, before the shaking takes place. Rumbling, or rushing noises, or sounds like the explosions of artillery, accompany the earthquake. The effects of earthquakes on the surface of the earth are various. Sometimes the ground is lifted up in a perpendicular direction; and sometimes is affected by a rolling, waving motion. Sometimes the shock commences with the perpendicular, and terminates with the waving horizontal motion. During an earthquake, fissures and chasms are frequently made, which sometimes close again, almost instantaneously, and sometimes remain open. In great earthquakes these fissures frequently swallow up human beings and other animals; and instances are recorded of their having engulfed whole towns at once.

Sometimes flame and smoke burst forth from the ground, when no openings were previously visible, and even from the waters of the sea.

The effects of earthquakes are felt by ships at sea, and often very powerfully. Sometimes an unnatural swell, or commotion, of the water, is observed, or an extraordinary, or a whirling movement. Sometimes when an earthquake is raging on the land, vessels receive a sudden blow, as if they had run aground, or struck against a rock. The effects of earthquakes are sometimes discerned at an amazing distance, from the chief seat of action, and at almost the same instant.

These dreadful agitations of the earth, have naturally exercised the understanding and at-

tention of philosophers in every age, and have been referred to various causes.

One of the most prevailing opinions, not only among the ancients, but also among the more modern philosophers, concerning the cause of earthquakes, is, that they are occasioned by the sudden rarefaction of water, and conversion into steam. Others imagine that the electrical fluid is the principal agent in these fearful commotions.

Deep wells are supposed to be preservatives against earthquakes; for, that giving vent to the effluvia, whatever they may be, that produce those concussions, they prevent the shocks, and thus prove a safeguard to the cities, and tracts of country, in which they abound. In some places wells are sunk for this purpose.

A Volcano is an opening made by subterranean fire, in the surface of the earth, through which vapour, smoke, flame, stones, cinders, ashes, streams of melted matter, called lava, and sometimes boiling water, and mud, are ejected, accompanied by uncommon and terrifying sounds.

Many volcanoes exist in lofty mountains, whose summits are shaped like truncated cones, in which are apertures generally circular and of various extent and depth. These apertures are called craters. Volcanoes are found in almost every part of the world, and the number of those known at present is not less than a hundred. The volcanoes in Europe, are Hecla in Iceland, Etna in Sicily, Vesuvius in Italy, and several in the Œolian or Lipari islands; of which

the principal, Stromboli, has thrown out flames without any other volcanic matter, for more than two thousand years. In Asia, there is a volcano on mount Taurus; some in the more central mountains, five in Kamtschatka; ten in the Japan islands, one on the peak of Adam in the island Ceylon, four in Sumatra. Volcanoes exist also on the African continent, and numbers in America and the South-sea islands.

Most of the active volcanoes are in the vicinity of the sea, or of large lakes, whence some geologists have inferred that water is a prime agent in volcanic eruptions.

The process of an eruption is generally as follows. The smoke usually emitted from the mountain augments rapidly, assuming the appearance of an accumulation of bales of white cotton, sometimes much larger than the whole bulk of the mountain itself. In the midst of this white smoke, a column of black smoke frequently rises, succeeded by reddish coloured flame. Showers of red hot stones are projected into the air, to an amazing height; and sometimes immense quantities of ashes are thrown to an astonishing distance. The lava, then, generally bursts forth from the top or the side of the mountain, in a torrent of liquid fire, overwhelming with destruction the gardens, vineyards, edifices, and towns which are in the way of its fatal progress. During an eruption from Mount Etna, a space of a hundred and fifty square miles was covered with dark-coloured sand or powder; and stones were shot up to the height of seven thousand feet. A stone was ejected

from Vesuvius, twelve feet long, and forty-five feet in circumference.

Volcanoes seem to become quite extinct, and after remaining for ages in that quiescent state, to be rekindled. Vesusius had been so long at rest, that pools of water had collected in the crater, and woods were growing in it, and on the sides of the mountain, when its fires revived, and burnt during a thousand years. Again, it was quiescent from 1136 to 1506; and it has now continued in action for three centuries.

Volcanoes are known to exist even at the bottom of the ocean; and these are called submarine volcanoes, and are few in number. Those which are certainly known are near the Azores and Iceland. By the force of volcanic eruption, islands have been raised from the bottom of the sea, and, after having been for some time visible, have disappeared.

Volcanoes have been ascribed to the effect produced by water bursting in suddenly upon some vast collection of fused or burning matter, to the action of central fires; and to the decomposition of different substances, by which heat and inflammation are produced.

Volcanoes, at astonishing distances, appear to be connected with one another. Steam is supposed to be one of the most powerful agents in volcanic operations.

Volcanoes have been observed in the moon by Herschel, Kater, and others.

QUESTIONS.

What are earthquakes, and what are the effects produced by them? To what causes are earthquakes principally at-

tributed? In what regions of the earth, do earthquakes take place most frequently? What phenomena usually precede and accompany earthquakes? What are volcanoes? What number of volcanoes are known to exist and in what parts of the world are they found? What are the general effects of volcanoes? In what situation with respect to the sea do volcanoes commonly exist? What substances do volcanoes usually throw out? To what causes are volcanoes chiefly referred? What is the general process of a volcanic eruption? Is there supposed to be any connection between distant volcanoes? Have any volcanoes ever been discerned in the moon?

CHAP XXXIV.

SOLIDS — STATICS — DYNAMICS.

A SOLID is a body, whose parts are so firmly connected together, as not easily to give way, or slip from one another. In this view, solid stands opposed to fluid.

Solids are commonly divided into regular and irregular.

Regular solids are those which are terminated by regular and equal planes, and are reckoned as being only five in number; namely, the tetrahedron, which consists of four equal triangles; the cube, or hexahedron of six equal squares; the octohedron, of eight equal triangles; the dodecahedron of twelve equal triangles; and icosahedron, which is composed of twenty equal triangles.

The irregular solids are almost innumerable; such as the sphere; the cylinder; the cone; the parallelogram; the prism; the parallelopiped, &c.

Statics, a term derived from the Greek word, signifying to weigh, is applied to that science which contemplates solids as at rest; considering their equilibrum, their weight, their pressure; while to the science which treats of the motions of solids, is given the name of dynamics, borrowed from the Greek word, signifying power.

Matter denotes the general substance of which all bodies are formed. Volume, or bulk, or magnitude, denotes the size of a body with regard to the space it occupies.

Density means the proportional quantity of matter which is contained within a given extension; and this quantity of matter is estimated by its weight.

Mass signifies both the bulk and density of a body; that is, the product of the bulk multiplied by the density.

The science called statics, comprehends all the doctrines of the excitement and propagation of pressure, through the parts of solid bodies, by which the energies of machines are produced.

It comprehends every circumstance which influences the stability of heavy bodies; the investigation and properties of the centre of gravity; the theory of the construction of arches, vaults, and domes, and the attitudes of animals.

It considers the strength of materials, and the principles of construction, so as to make the proper adjustment of strength and strain, in every part of a machine, edifice, or structure of any kind. It furnishes, consequently, the theory

of carpentry, and gives instructions for framing floors, roofs, centres, &c.

The science of statics comprehends, also, the whole doctrine of the pressure of fluids, whether liquid (in which case it receives the name of hydrostatics) or aëriform, when it is called aërostatics. Hence is derived the knowledge of the stability of ships, or their power of maintaining themselves in a position nearly upright, in opposition to the action of the wind on their sails.

Motion is a continual and successive change of place.

Motion is generated by certain causes; by particles of matter, which possess peculiar properties, stimulating or exciting nerves and organs; or decomposing bodies; by the operation of animal power; by the force of gravitation, or of other natural agents, such as wind, water, steam. The original source of all motion is the great First Cause, the glorious Creator of all things.

Equable motion is that movement of a body which passes over equal portions of extension, or of space, in equal portions of time.

Accelerated and retarded motion is, when equal portions of extension are passed over in portions of time, either successively smaller, or successively larger; or accelerated motion is that which, by some constantly operating cause, is continually increasing, as is exemplified in a body falling from some considerable height, whose motion is augmented in regularly increasing ratio, during every instant of its fall. This ratio

is, as the numbers 1, 3, 5, 7, 9, &c. For instance, if a body fell eight feet in the first second of its fall, it would fall three times eight in the next; five times eight in the third second; seven times eight in the fourth second, and so on.

Retarded motion is that which, by some constantly operating cause, is continually decreasing. For instance, if an arrow were shot straight upward, its motion would be diminished every instant of its ascent, till, its direction being changed, it would descend with accelerated motion, in the same time as its ascent took.

The whole spaces through which a falling body passes, from the commencement of its motion, will be as the squares of the times. That is, if it fall eight feet in the first second, it will fall four times eight in two seconds; nine times eight in three seconds; sixteen times eight in four seconds; and thus on; since, 4, 9, 16, are the squares of 2, 3, 4.

Velocity is the ratio of the quantity of lineal extension that has been run over in a certain given portion of time.

A force is that which causes a change in the state of a body, whether of rest or of motion.

The momentum, or quantity of motion, is the force of a body in motion; and is equivalent to the impression which it would make on another body, that should be placed, at rest, just before it.

A pressure is a force which acts upon a body so as to put it in motion, and, by the continuance of the action, accelerates that motion. Of this

kind is the force of gravity, which by constantly acting upon descending bodies, continually accelerates their velocities.

An impulse is that force which acts instantaneously upon a body, according to our perception, and then leaves the body, without repeating the act. Such is the stroke of a hammer; or of one body impinging upon another.

For the sake of perspecuity, the science of dynamics arranges the different movements of bodies under the following heads:—

Uniform, rectilinear motion.

Collision, both direct and oblique.

Motions arising from the actions of central forces.

Motions arising from the joint actions of a central, and an impulsive force; that is, of a pressure and an impulse.

Projectiles.

Descent of bodies along inclined planes.

Vibrations of pendulums.

Curve of swiftest descent.

Rotation of bodies about fixed axes.

Centres of oscillation, of percussion, of gyration.

Movements of machines.

There are three rules applicable to all these kinds of motion, which are commonly denominated Newton's laws of motion.

First. Every body will remain in a state of rest, or of uniform motion in a straight line, unless it be compelled to change that state, by forces impressed.

Second. The change of motion is always

proportionate to the moving force impressed, and is always made in the direction of the right line in which that force is impressed.

Third. Action and reaction are always equal and contrary to each other. Or, the mutual actions of two bodies upon each other, are always equal, and directed contrary ways.

The following theorem is one of the most important in dynamics, and of the most extensive use in mechanics, the practical application of the former.

If a body be acted upon by two moving forces at the same time, so that each of those forces would, by itself, cause it to describe the side of a parallelogram, uniformly in a given time; the body, in consequence of their joint actions, will describe the diagonal of that parallelogram, uniformly in the same time.

The line of swiftest descent is a curve called the cycloid, in which a body will descend from a superior to an inferior place, not in the same perpendicular, in less time, than along a straight line.

When a body is suspended by a flexible string, or by a pin which, passing through a hole in it, is fixed to a steady support; or whenever a body hangs down from any point, so as to be capable of swinging about that point, it is called a pendulum, or pendulus body; and as pendulums are of most extensive use in mechanics, their properties have been investigated with great attention, both theoretically and experimentally.

That point from which the length of the pendulum to the point of suspension must be

reckoned, is called the centre of oscillation, or of percussion.

The centre of gyration is that point in a body, or system of bodies, in which, if all their matter were condensed, the same angular velocity would be generated in a given time, that would be generated in the whole body, or system, by the same force similarly applied.

The centre of spontaneous gyration is a point about which a body begins to revolve at the instant when it is struck by a force acting out of its centre of gravity.

QUESTIONS

What is a solid? How are solids generally divided? What are the regular solids? What are the irregular solids? What is the science, termed statics, and what objects does it comprehend or regard? What is volume? What is density? What is mass? What accelerated and retarded motion? What is the science is named dynamics? What is equable motion? What is velocity? What is a force? What is momentum? What is a pressure? What is an impulse? How does the science of dynamics arrange the various movements of bodies? What are Newton's three laws of motion? What is the theorem concerning a body acted upon by two moving forces at the same time, in certain different directions? What is the line of swiftest descent? What is a pendulum? What is the centre of oscillation or percussion? What is the centre of gyration? What is the centre of spontaneous gyration?

CHAP. XXXV.

MECHANICS.

By the science of dynamics two important ends are answered. The human being is enabled to comprehend and to explain some of the grandest phenomena of nature; and he is furnished with machines, which enable him to perform operations, and to produce effects, far beyond his unaided corporeal powers.

Sir Isaac Newton first conceived the sublime idea of a general connection between the most distant bodies of the universe. He imagined that the celestial bodies were actuated and connected by a general and mutual gravitation, or tendency towards one another, and towards a common centre. Desirous of proving the conception of his vast and vigorous mind, he began by endeavouring to investigate the laws of such forces, or gravitating powers; and proceeding from truth to truth, he at last formed an ample demonstrative theory. His next step was to examine how far astronomical observations were conformable to that theory; and he was gratified to find a coincidence so exact, as to confirm the justness of his supposition. Mathematical improvements, more accurate observations, and farther discoveries that have been made since his time, have brought the science so near to perfection, that it is now possible to calculate and to foretel the nicest astronomical phenomena; whence have been derived incalculable ad-

vantages, especially in navigation. But the application of the science of dynamics to mechanics, is, perhaps, of yet greater and more extensive utility: for this gives man a command over some of the most powerful agents in the natural world; wind, water, steam, heat, and many others.

The term mechanics is given to that branch of practical mathematics which considers motion, and moving powers, their nature, laws, and effects. This science is divided, by Newton, into practical and rational mechanics; the former of which relates to the mechanical powers, and the latter to the theory of motion.

SIMPLE MACHINES, OR MECHANICAL POWERS.

The simple machines, or mechanical powers, are usually accounted to be the six following:—the lever, the wheel and axle, the pulley, the inclined plane, the wedge, and the screw.

A lever is an inflexible bar, or rod, moving freely round a point, called its fulcrum, or centre of motion. Levers have generally been considered as being of three kinds. The first kind of lever has the fulcrum between the power which acts, and the weight which is to be raised. To this kind of lever belong the steelyard, scissors, pincers, and other useful implements. The second kind of lever has the weight between the power and the fulcrum. To this kind of lever belong cutting knives fastened to handles at each end, and the oars of a boat, where the water is regarded as the fulcrum. In the third kind of

lever the power is between the weight and the fulcrum. To this sort of lever are referred tongs, sheers for cutting wool from the sheep, and the bones of animals.

The wheel and axle. This machine consists of a wheel and cylinder, having the same axis, and moving upon pivots placed at the extremity of the cylinder. The power is usually applied to the circumference of the wheel, and acts in the direction of a tangent, while the weight is elevated by a rope which coils round the cylinder in a plane perpendicular to its axis. The wheel and axle is, in fact, an assemblage of levers.

The pulley.—The pulley is a machine composed of a wheel with a groove in its circumference, and a rope that passes round in the groove. The wheel moves on an axis, whose extremities are supported on a kind of frame, called the block, to which is generally suspended the weight to be raised. A system of pulleys, connected together to increase the power, is called a muffle; and this is either fixed or moveable, according as the block that contains the pulleys, is fixed or moveable. A single pulley, fixed, does not increase the power, but merely changes the direction of the weight. The moveable pulley, to which the weight is attached, rises and falls with it, and augments the moving force in the proportion of two to one. Thus, a power of six pounds will balance a weight of twelve pounds, because the power moves through a space twice that which the weight does.

In order to find the increase of power gained

by any number of pulleys, multiply the number of pulleys in the lower block by two.

The inclined plane.—An inclined plane is a plane surface, supported at any angle, formed with a horizontal plane. The body which is required to be elevated is rolled up this plane, instead of being lifted perpendicularly by a man's arms, and thus a considerable part of the weight is supported upon the plane, and, consequently, a smaller degree of force is necessary to raise it.

The wedge.—A wedge is a machine composed of two inclined planes, with their bases in contact; or, more properly, it is a triangular prism, generated by the motion of a triangle parallel to itself, along a straight line, passing through the vertex of one of its angles. The wedge is called isosceles, rectangular, or scalene, according as the triangle by which it is generated is an isosceles, a rectangular, or a scalene triangle. The wedge is generally employed for cleaving wood, or quarrying stone; but all cutting instruments properly belong to this mechanical power, when they act at right angles to the cutting surface; for when they act obliquely, in which case their power is increased, their operation resembles more the operation of a saw.

The screw is a cylinder, having an inclined plane wrapped round it in such a manner, that the surface of the plane is oblique to the axis of the cylinder, and forms the same angle with it, in every part of the cylindrical surface. When the inclined plane winds round the exterior surface of a solid cylinder, it is called a male screw; but when it is fixed on the interior

circumference of a cylindrical tube, it is called a female screw. This compound machine, by the improvements which it has received, has, now such power, that a man, by exerting a force of thirty-two pounds at the winch by which the screw is turned, will produce an effect of 57,600 pounds, allowing one third for the diminution of the original force by friction. The screw is of extensive use, as a mechanical power, when any very great pressure is required. It is employed, with powerful effect, in the printing press, in the press for coining money, in raising water; and it is of great use in subdividing any space into a great number of minute parts. Hence it is employed in engines for dividing mathematical instruments, in instruments employed in engraving, in the common wire micrometer, and in the divided object glass micrometer.

To these six mechanical powers are added, by some writers, the balance and the rope machine. The balance is a lever of equal arms, for determining the weights of bodies, and is now brought so near to perfection as to effect this purpose with the greatest nicety.

When a body, suspended by two or more ropes, is sustained by powers acting by the assistance of these ropes, this assemblage of ropes is called a rope machine.

QUESTIONS.

What is the science of mechanics? What is the general division of mechanics adopted by Sir Isaac Newton? What are the simple machines, or mechanical powers? What is the lever? The wheel and axis? The pulley?

The inclined plane? The wedge? The screw? To what purposes is the wedge applied? To what purposes is the screw applied? What is the balance, and what is its use? What is the rope machine?

CHAP. XXXVI.

MECHANICS—continued.

THE centre of gravity, or, as it is likewise called, the centre of inertia, of any body, or of any system of bodies, is that point upon which the body, or system of bodies, when influenced only by the force of gravity, will be in equilibrio in every position.

Several methods for finding the centre of gravity have been invented; and from these, and the consideration of the subject, many useful inferences have been derived, and many important theorems formed.

If a body be placed upon a horizontal plane, or suspended by two strings, it cannot be in equilibrio, unless a perpendicular, drawn from the centre of gravity to the horizontal plane, or to a horizontal line, passing through the two strings, fall within the base of the body, or upon that part of the horizontal line which lies between the threads.

The perpendicular is called the line of direction.

As long as the line of direction is within the base of a body, such as a wall or tower, that

body will not fall, however much it may appear to the eye to lean; which accounts for the extraordinary appearance exhibited by some edifices, or parts of edifices, of inclining greatly from their perpendicular, without actually falling.

If a body be placed upon an inclined plane, supposed without friction, it will slide down the plane, when the line of direction falls within its base; and will roll down it, when the line of direction falls without the base of the body.

The higher the centre of gravity of any body is, the more easily is that body overturned. This shows the danger of starting up suddenly in a boat, and of loading a carriage at its top; because by so doing, the centre of gravity is raised high, and the boat or carriage is more liable to be overset.

Bodies are said to have a stable equilibrium, when their centre of gravity cannot move without ascending. Bodies are said to have a tottering equilibrium, when their centre of gravity cannot move without descending. Bodies are said to have a neutral equilibrium, when they will rest in any position.

Bodies stand more firmly, and are less easily overthrown, in proportion to the breadth of the base on which they stand.

Many phenomena in the equilibrium and motion of animals, are deducible from the properties of the centre of gravity. Children learn by experience to keep the line of direction within the base, in the various movements of their bodies, in walking, rising, stooping, sitting down. When we ascend an inclined plane, the body is mecha-

nically thrown farther forward than when we walk on a horizontal plane, that the line of direction may fall without our feet; and in descending an inclined plane, the body is thrown backward, in order to prevent the line of direction from falling too suddenly without the base. In carrying a burden, the centre of gravity is brought nearer to the burden, so that the line of direction would fall without the feet, if the man did not naturally lean towards the side opposite to the burden, in order to keep the line of direction within the base of the feet. When the burden is carried on the back, the person carrying it leans forward; when it is carried on the right arm, he leans towards the left; when carried on the left arm, he leans towards the right; and when the burden is carried before the body, the head is thrown backwards, for the same purpose.

Friction is the great obstacle to the desired operation of the mechanic powers, in the various machines which human art has invented for the conveniences of social life. The friction generated in the communicating parts of machinery, opposes a great resistance to the impelling power, and is injurious to the machines themselves; and, therefore, many methods have been devised, and are used, for diminishing the friction, and lessening the resistance it opposes to the movements of machines. The most efficacious mode of accomplishing this is, to convert that species of friction which arises from one body being dragged over another, into that which is occasioned by one body rolling upon

another. This may be easily effected by applying wheels, or rollers, to the sockets which sustain the axles of wheels. The effects of friction are diminished, likewise, by a judicious application of the impelling power, and of unguents of grease and tallow, when the surfaces are made of wood; and of oil when they consist of metal. In small works made of wood, the interposition of the powder of black lead has been found very useful in relieving the friction.

A fly-wheel is a heavy wheel or cylinder, which moves rapidly upon its axis, and is applied to machines, to render uniform a desultory or reciprocating motion, arising either from the nature of the machinery, or from an inequality in the resistance to be overcome, or from an irregular application of the impelling power. When the moving power is inanimate, as wind, water, or steam, an inequality of force may arise from variations in the velocity of the wind, from the increase or decrease of water, or from the augmentation or diminution of steam. The same inequality of force may take place, also, when machines are moved by animals. A fly-wheel, consisting either of cross bars, or a massy, circular rim, removes this inconvenience.

QUESTIONS.

What is the centre of gravity? What is the line of direction? How must the line of direction be situated to prevent any body from falling? What situation of the centre of gravity renders a body most liable to be overset? When are bodies said to have a stable equilibrium? When are bodies said to have a tottering equilibrium? When are bodies said to have a neutral equilibrium? How do bodies stand most firmly?

What phenomena in the equilibrium and motions of animals are deducible from the properties of the centre of gravity? What is the great obstacle to the free operation of the mechanic powers? By what methods is friction diminished? What is the fly-wheel?

CHAP. XXXVII.

HYDRODYNAMICS.

HYDRODYNAMICS, a term compounded of two Greek words, signifying water and power, is given to that science which treats of the power of water, whether acting by pressure or by impulse. In its more enlarged acceptation, however, it treats of the pressure, equilibrium, cohesion, and motion of fluids, and of the machines by which water is raised, or in which it is employed as the first mover. Hydronamics is divided into two branches; hydrostatics and hydraulics. Hydrostatics contemplates the pressure, equilibrium, and cohesion of fluids; and hydraulics, their motions, with the machines in which they are chiefly concerned.

Hydrostatics regards the pressure and equilibrium of non-elastic fluids, as water, oil, mercury, and others such; the method of determining the specific gravities of substances, the equilibrium of floating bodies, and the phenomena of capillary attraction.

A fluid is a collection of very minute particles, adhering so little among themselves as to yield to

the smallest force, and to be easily moved among one another.

Fluids have been divided into perfect and imperfect. In perfect fluids, the constituent particles are supposed to be endowed with no cohesive force, and to be moved among one another, by a pressure infinitely small. In imperfect, or viscous fluids, the mutual cohesion of their particles is very sensible, as in oil, varnish, melted glass, &c. and this tenacity prevents them from yielding to very small pressure.

Till within some few years, it was generally believed that water, mercury, and other fluids of a similar kind, could not be made to occupy a smaller space, by the application of any external force. This opinion was founded on an experiment made by Bacon, Lord Verulam, who inclosed a quantity of water in a leaden globe, and by applying a great force, endeavoured to compress the water into less space than it occupied at first. The water made its way through the pores of the metal, and stood upon its surface like dew. A similar experiment was performed at Florence. A silver globe was filled with water, and by means of the screw, a violent power was made to act upon it. As in Bacon's experiment, the water was driven through the pores of the metal. In consequence of the reliance placed on these experiments, fluids have been divided into compressible and incompressible; or elastic and non-elastic.

Water, oil, alcohol, and mercury, were regarded as incompressible and non-elastic; and air, steam, and other aëriform fluids, as com-

pressible or elastic. But subsequent to this, experiments made by Canton and Zimmerman, have proved that fluids are capable of contraction and dilation, and that there is no foundation in nature for their being divided into compressible and incompressible. If fluids are compressible, they must also be elastic; for when the compressing force is removed, they will recover their former magnitude. Hence their division into elastic and non-elastic is equally improper.

When fluids are subjected to any pressure, that pressure is diffused throughout the mass in such a manner, that when it remains in equilibrio all its parts are equally pressed in every direction.

The pressure of fluids acts equally in every direction, upwards, sideways, and downwards.

The surface of a fluid influenced by the force of gravity, and in equilibrio, in any vessel, is horizontal, or at right angles to the direction of gravity.

The surface of a fluid influenced by the force of gravity, and contained in any number of vessels communicating with one another, however different they may be in form and position, will be horizontal.

This principle is the cause that fluids always find their level, when not obstructed in their natural pressure. Upon this property depends the natural rise of water in fountains and tubes, to the height of the spot and spring whence it first issues. This explains, also, the reason why the surface of small pools in the vicinity of

rivers, is always on a level with the surface of the rivers themselves, when there is any subterraneous communication between such pools and rivers. The rivers and the pools may be considered as communicating vessels.

The pressure of water is not proportionate to its quantity, but to the perpendicular height at which it stands.

Any given quantity of water may exert a greater or less force, according as its perpendicular height is greater or less.

The pressure upon any given portion of the bottom of a vessel, filled with any fluid, is equal to the weight of a column of fluid, whose base is equal to the arēa of the given portion, and whose altitude is the mean altitude of the fluid. From this proposition is deduced what is generally called the hydrostatic paradox; namely, that the pressure upon the bottoms of vessels, filled with fluid, does not depend upon the quantity of fluid which they contain, but upon its altitude; or, that any quantity of fluid, however small, may be made to balance any quantity, or any weight, however great, by increasing the height of the column, and diminishing the base on which it presses.

QUESTIONS.

Of what does the science, called hydrodynamics, treat? What are the two branches of hydrodynamics? What are the objects of which hydrostatics treats? What are the objects of hydraulics? What is a fluid? What is the difference between perfect and imperfect fluids? What experiments occasioned the division of fluids into compressible or

incompressible; elactic or non-elastic? Is this division of fluids retained? In what manner is pressure diffused through fluids? How does the pressure of fluids act? How does the surface of a fluid influenced by the force of gravity, and in equilibrio in any vessel, stand with respect to the direction of gravity? What is the position of the surface of a fluid influenced by the force of gravity, and contained in vessels or tubes communicating with one another? What are the results of that position of a fluid so situated? To what is the pressure of water proportionate? To what is the pressure on any given portion of the bottom of a vessel filled with any fluid, equal? What is the hydrostatic paradox?

CHAP. XXXVIII.

HYDRODYNAMICS—continued.

SPECIFIC GRAVITIES.

The absolute weights of different bodies of the same bulk are called their specific gravities, or densities; and one body is said to be specifically heavier, or specifically lighter, than another; when, under the same bulk, it contains a greater or less quantity of matter. Thus, brass is said to have eight times the specific gravity of water, because one cubic inch of brass contains eight times the quantity of matter, or, is eight times heavier than a cubic inch of water. The specific gravities of bodies, or their relative weights to equal bulks of different bodies, are found by weighing them in water.

Any body immersed in a fluid, or floating on its surface, is pressed upwards with a force equal to the weight of that quantity of the fluid which it displaces.

Thus, every body which swims in water, or that sinks in it, displaces just as great a quantity of the water as is equal to the bulk or weight of that body.

A solid, weighed in a fluid, loses as much of its weight as is equal to the weight of the quantity of fluid displaced by it.

A solid, immersed in a fluid, will sink, if its specific gravity exceed that of the fluid; but if its specific gravity be less than that of the fluid, the solid will float on the surface, partly immersed; and if the specific gravities of the solid and fluid be equal, the solid will remain wholly immersed, wherever it is placed.

The specific gravities of two or more fluids, are to one another, as the losses of weight sustained by the same solid body, specifically heavier than the fluids, when weighed in each fluid respectively.

The specific gravity of a solid is to that of a fluid as the absolute weight of the solid is to the loss of weight which it sustains, when weighed in that fluid.

The specific gravity of a solid floating in a fluid, is to the specific gravity of the fluid itself, as the bulk of the part immersed is to the total bulk of the solid.

Bodies which sustain equal losses of weight are of the same bulk.

Hence is deduced a method of detecting

adulteration of the precious metals. Take a real guinea of gold, and a counterfeit guinea of copper, and if their weight be apparently the same, let them be weighed in water, and let the loss of weight, which each sustains, be accurately observed, and it will be found that the false coin will lose more of its weight than the true coin. For as the specific gravity of gold exceeds that of copper, and as the absolute weights of the two coins were equal, the counterfeit guinea must be greater in bulk than the real guinea, and will, therefore, displace a greater quantity of water; that is, will lose a greater part of its weight.

This was, probably, the method which Archimedes employed to discover whether a golden crown, submitted to his examination by Hiero, king of Syracuse, who suspected the honesty of the artist by whom it was made, contained the quantity of gold given to him by the monarch for that purpose, or not. A quantity of gold of the same absolute weight as the crown, would, evidently, have the same bulk also, if the crown were made of pure gold; but would have a greater bulk if the crown were formed of adulterated gold. Therefore, by weighing in water, the crown, and a quantity of pure gold equal to that which had been entrusted to the artist, and observing their respective losses of weight, Archimedes found that the crown lost more of its weight than the mass of gold, and consequently concluded, that as the crown must have displaced a greater portion of water than the piece of gold, its bulk must also have

been greater, and that, therefore, the metal of which it was composed was adulterated.

From these premises follows the rule for finding the specific gravities of such solids as sink in water. First, weigh the body in the usual way, and afterwards in water.

Divide the first weight by what it has lost in the water, and the quotient will be the specific gravity of the body.

Water is the fluid generally used for weighing substances, in order to deduce their specific gravities, from the losses of weight which they severally sustain; because pure rain water is of the same weight in every different part of the globe. A cubic foot of it weighs one thousand ounces avoirdupois; therefore the specific gravity of water is called 1,000; and with this, as a standard, the specific gravity of every other substance is compared. Thus if a certain quantity of water weighed four pounds and a similar quantity of mercury weighed fifty-six pounds; the specific gravity of the mercury would be called 14; because 4 : 56 : : 1 : 14.

To determine the densities of bodies in this way, only a common balance is necessary, with a hook fixed beneath one of its scales. This instrument is called the Hydrostatic balance.

An instrument, called a Syphon, is employed to show the gravitation of fluids, and is frequently used for decanting liquors.

This is merely a bent tube, having one of its legs longer than the other. The shorter leg is immersed in the fluid contained in a vessel; and if the air be sucked out of the tube, the liquor

will flow off, till the vessel be completely emptied.

CAPILLARY ATTRACTION.

When water is poured into a vessel, or into any number of communicating vessels, its surface will be horizontal; or, it will rise to the same height in each vessel, whatever be its form or position. This is the fact, however, only when the diameter of the communicating vessels or tubes exceeds the fifteenth of an inch; for if a set of communicating vessels be composed of tubes of various diameters, the fluid will rise to a level surface in all the tubes which exceed one fifteenth of an inch in diameter; but if there be tubes of a smaller diameter in them, the fluid will rise above that level, to heights inversely proportional to the diameters of the tubes. The power by which the fluid is thus raised above its natural level, is called capillary attraction; and the glass tubes which are employed to exhibit its phenomena, are named capillary tubes. These appellations are derived from a Latin word, signifying a hair. This power has not yet been satisfactorily accounted for, though its operations have been traced and calculated.

The fluidity of water is increased by heat. It has been proved by experiment, that a jet of warm water will spring much higher than a jet of cold water, and that a syphon which discharges cold water only by drops, will discharge water of a high temperature in a continued stream.

This fact was observed by the ancients; for Plutarch remarks that the clepsydræ, or water clocks go faster in summer than in winter, and he attributes this to the influence of heat.

A clepsydra, or water-clock, is a machine which measures the lapse of time by the descent of water in a vessel. If such a form be given to a vessel that the areas shall increase uniformly, as the times; then the times in which the surface of any fluid, contained in that vessel, descends, by running out through an orifice in its side or bottom, will be in the same ratio, and the vessel will form a machine for measuring time. If the vessel be cylindrical, and empty itself in twelve hours, its altitude may be divided in such a manner, that the fluid surface may take exactly an hour to descend through each division.

In order to determine, with expedition, the strength of spirituous liquors, which is inversely proportional to their specific gravities, an instrument is employed, called, Hydrometer, or arcometer, or gravimeter; the invention of which is attributed, by some, to Archimedes; by others, the honour is assigned to a female named Hypathia, who flourished towards the end of the fourth century.

Fahrenheit's hydrometer made of glass or metal, consists of a cylindrical stem graduated, and having two hollow balls of unequal sizes attached towards the same end of it. Into the lowermost of these, or that quite at the end, is introduced quicksilver enough to make itself and the other ball sink a little below the surface of distilled water. If this apparatus be plunged

into a fluid lighter than water, the larger ball will sink below the surface, and if it be immersed in a heavier fluid, it will rise nearer the surface.

QUESTIONS.

What are the specific gravities of bodies? In what manner is any body immersed in a fluid, or floating on its surface, pressed? What quantity of water is displaced by any body which swims or sinks in it? When a solid is weighed in a fluid, how much of its weight does it lose? When will a solid immersed in a fluid, sink, or float, or remain wherever it is placed? What is the proportion between two or more fluids, as to their specific gravities? What is the proportion between the specific gravity of a solid and that of a fluid? What is the proportion between the specific gravity of a solid floating in a fluid, and the specific gravity of the fluid itself? When are bodies said to be of the same bulk? What is the method of detecting the adulteration of the precious metals? How did Archimedes discover the adulteration of Hiero's golden crown? What is the rule for finding the specific gravities of such solids as sink in water? What fluid is generally used for weighing substances, in order to find their specific gravities? What is the hydrostatic balance, and by what other names is it called? What is a syphon? What is Fahrenheit's hydrometer? What is capillary attraction?

CHAP. XXXIX.

HYDRODYNAMICS — continued.

HYDRAULICS. — Hydraulics is that branch of hydrodynamics which teaches how to estimate the velocity and force of fluids in motion. This,

consequently, comprehends the theory of running water, whether issuing from openings in reservoirs, impelled by the pressure of some substance lying above them, or rising perpendicularly from atmospherical pressure; or raised in pumps, or other machines, invented by human art.

If water issue from an orifice in the side or bottom of a reservoir of any kind, its surface remains in a horizontal position, maintaining its level, till it nearly reach the bottom; all its particles descending in vertical lines. But then, the particles change the direction of their motion, and rush towards the opening, in different degrees of obliquity. If some small substances specifically heavier than water, be thrown into the fluid while it is running out through the orifice, they will, at first, descend vertically; but when they approach near to the bottom, they will deviate from this direction, and will describe oblique curves. A contraction in the vein or column of descending fluid is, also, manifest from observation. It was first observed by Sir Isaac Newton, and denominated the vena contracta, or the contracted vein.

The velocity with which water runs from an opening in the bottom or side of a vessel, is estimated to be proportionate to the square root of the distance of the surface of the water, to the opening.

For instance; if the velocity of water, running through an orifice, at the distance of one foot beneath the surface, be estimated at 1; then, if

flowing through an opening four feet beneath the surface, the velocity will be as 2; and if the hole through which it flows, be nine feet below the surface, the velocity will be as 3.

The lateral pressure of water, that is, its pressure against the sides of the reservoir containing it, is as the square of the depth of the reservoir.

Thus, in a vessel of water three feet deep, at the depth of one foot, the pressure of the fluid against the sides will be 1; at the depth of two feet, it will be 4, and at the depth of three feet, it will be nine.

By means of its property of pressing equally every way, water may be conveyed in pipes, over hills and through valleys, to any distance, and to any height, not exceeding that of the spring whence it first issues.

This is the principle upon which water-works and aqueducts are constructed.

When a fluid issues vertically, from any containing reservoir, it will rise to a height equal to the perpendicular distance of the orifice by which it issues, from the surface of the fluid. Owing, however, to the resistance of the air, and the friction of the issuing fluid against the sides of the orifice, jets of water do not rise to exactly that height.

The oscillations of water in a syphon, consisting of two vertical branches and a horizontal branch, are isochronous, that is in equal times; and they have the same duration as the oscillations of a pendulum, whose length is equal to

half the length of the oscillating column of water.

The undulations of waves, are performed in the same time as the oscillations of a pendulum, whose length is equal to the breadth of a wave, or to the distance between two neighbouring cavities or eminences of water.

QUESTIONS.

What branch of hydrodynamics is named hydraulics? What is the vena contracta of Sir Isaac Newton? How is water, running from an opening in the bottom, or side of a vessel, estimated? What is the proportion of the lateral pressure of water? Upon what principle, or what property of fluids, are water-works and aqueducts constructed? When a fluid issues vertically from an orifice, how high will it rise? In what times are the oscillations of water in a syphon performed? In what times do the undulations of waves take place?

CHAP. XL.

HYDRODYNAMICS — continued.

HYDRAULIC MACHINES.

WATER-WHEELS. — Water-wheels are of three kinds; overshot-wheels; breast-wheels; and undershot-wheels; which derive their names from the manner in which the water is applied to their circumferences.

An overshot-wheel, is a wheel set in motion, and continued in motion, by the weight of water, conveyed into buckets disposed on its circumference.

The diameter of an overshot-wheel, cannot exceed the height of the fall of the water which turns it; but it should be of nearly the same length.

The more slowly an overshot-wheel moves, the more work will it do.

In overshot-wheels, the power is to the effect as three to one.

An undershot-wheel, is a wheel with a number of float-boards disposed on its circumference, which receive the impulse of the water, conveyed to the lowest point of the wheel, by an inclined canal. The number of the float-boards should be as great as possible. Their figure should not be exactly rectangular, but bevelled, or rounded off, at the extremity farthest from the wheel, and somewhat inclined to its radius.

A breast-wheel partakes of the nature both of an over-shot, and an undershot-wheel. It is driven partly by the impulse, but chiefly by the weight of the water.

This wheel is furnished with float-boards, like the under-shot wheel; but the stream of water falls upon it, nearly parallel to its centre.

Buckets are sometimes used with breast-wheels; but they are not found to be so effectual as float-boards.

Pumps.—The pump was invented by Ctesibius, a mathematician of Alexandria, who flourished about 120 years before the Christian era. In its original state it was rude and imperfect; but from it are derived the various kinds of pumps in use at present.

The sucking, or common pump.—This useful machine consists of a hollow trunk, or large tube, made of wood or metal, an open end of which is immersed in the water, and a moveable piston, which is a box, or bucket, attached to a rod that is raised or depressed in the trunk, by means of an arm or lever. The open side of the box is downwards; and in the closed side, which is uppermost, there is a valve lying close upon the opening which it covers, till the working of the engine commences. Farther down in the trunk, is another such box or bucket, but fixed; this, likewise, has a valve in its closed and upper side. The valves are made of brass, and their lower surfaces are covered with leather in order to close the holes in the boxes more exactly. The moveable box is covered with leather also, so as accurately to suit the bore of the trunk, and prevent any air from escaping. When the piston is drawn up, a vacuum is made between the fixed and the moveable box. The water,, which is below the fixed box, or bucket, pressed by the atmospherical air, rushes into it, opens the valve, gradually ascends through the valve in the upper box, and issues forth at an opening in the trunk, made for that purpose. As the water rises in the trunk, or pipe, solely by the pressure of the atmosphere; and as a column of water, thirty-three feet high, is equal in weight to a column of air of the same base, reaching from the earth's surface to the top of the atmosphere, the water in the trunk will not follow the moveable piston to a greater height than thirty-three feet; for,

when it reaches this altitude, the column of water completely balances the column of the atmosphere of the same diameter, and, therefore, cannot be raised higher by the pressure of such a column of air.

The forcing pump.—In this machine the moveable piston is composed of a rod, and a solid plunger or box, instead of an open one, as in the common pump; the operation of which is to force out the water, raised in the trunk by atmospherical pressure, through a rectangular pipe, into an air vessel fastened to it, into which air vessel is introduced a tube approaching as nearly as possible to the valve of the pipe by which the water enters. The air in that vessel has no communication with the external air, when the water has attained to a certain height therein; and, therefore, as fresh quantities of water are injected from the trunk through the rectangular pipe into the vessel, the air must be condensed more and more. It will then endeavour to expand itself, and by pressing upon the surface of the water received into the air vessel, it will drive the water up through the tube in a continued stream.

The lifting pump is only a particular modification of the forcing pump, in which the effect of raising the water is produced by the artificial pressure of a frame, let down into the fluid together with the trunk.

The chain pump.—The chain pump consists of a chain about thirty feet long, carrying a number of flat pistons, which are made to revolve in two barrels, or trunks, by driving a

wheel. When the flat pistons are at the lower part of the barrel in which they descend, they are immersed in the water; and as they rise in the other barrel, they bring up the water along with them into a reservoir, from which it issues through a sprout.

The common fire engine is a modification of the lifting pump. The frame and piston force the water into a cylinder, whence it is driven into flexible leathern tubes, and conveyed, or discharged to considerable distances. But as this does not afford a continued stream of water, but only throws it out in successive jets, others have been invented, which, by discharging an uninterrupted current, are much more efficacious in the extinguishing of fires.

The screw engine of Archimedes is a cylinder with a flexible pipe carried round its circumference, like a screw. The cylinder is inclined to the horizon, and supported, at one extremity, by a bent pillar, while its other extremity, furnished with a pivot, is immersed in the water. When, by means of a handle, the cylinder is made to revolve upon its axis, the water which enters the lower orifice of the flexible pipe is raised to the top, and discharged into a reservoir. The Persian wheel is an engine which raises water to a height equal to its diameter. This wheel is driven round by a stream of water acting upon float-boards fixed on one side of its rim; while on the opposite side are suspended, by strong pins, a number of buckets. When the wheel is set in motion, the descending buckets plunge into the stream, and ascend full of

water till they reach the top, when they strike against the edge of a fixed reservoir, and being turned over by the stroke, they empty their contents into that reservoir.

Sometimes the Persian wheel is made to raise water only as high as its axle. In this case, instead of buckets, the spokes of the wheel are constructed of a spiral form, and hollow; so that their inner extremities all terminate in a box, at the axle, and their outer extremities in the circumference of the wheel. When, therefore, the rim is immersed in the stream, the water runs into openings in it, and thence through the spiral spokes into the reservoir at the axle, whence it is discharged, or is conveyed in pipes.

The Clepsydra, invented by Ctesibius of Alexandria, was an interesting machine. The water which measured the progress of time by the gradual descent of its surface, flowed in the form of tears from the eyes of a human figure. Its head appeared bent down with age; its look was dejected; while it seemed to pay the last tribute of regret to the fleeting moments as they escaped. The water thus discharged, was collected in a vertical reservoir, where it raised another figure, holding in its hand a rod, which, by its gradual ascent, pointed out the hours upon a vertical column. The same fluid was afterwards employed in the interior of the pedestal, as the impelling power of a piece of mechanism, which made this column revolve round its axis in a year, so that the months and days were always shown by this index, whose extremity de-

scribed a vertical line, divided according to the relative lengths of the hours of day and night.

QUESTIONS.

What is the overshot wheel? What is the undershot wheel? What is the breast-wheel? What is the Persian wheel? By whom was invented the machine called the pump? What is the common, or sucking pump? What is the forcing pump? What is the lifting pump? What is the chain pump? What is the fire engine? What is the screw-engine of Archimedes? What was the clepsydra of Ctesibius of Alexandria?

CHAP. XLI.

PNEUMATICS.

THE science which contemplates the mechanical properties of all elastic, or sensibly compressible fluids, is termed pneumatics. Of all these fluids, air is the most familiar to human observation, and was, consequently, the first studied, and the most minutely examined.

Air is a material fluid: a fluid because its parts are easily moved; and material, since it has impulsive force; impenetrability, elasticity, inertia, and weight. All these assertions are proved by experiments.

Air is material, since it offers sensible resistance to the hand, or a fan, or any other body moved quickly in it.

Air is elastic; for it can be compressed into a much less space than it usually occupies. When

the compressing power is removed, it regains its former space and situation, with a force equal to the compressing force.

Air has weight or gravity; for if a vessel be emptied of air, it weighs less than when it is full of air. It supports the clouds and vapours. Certain bodies, such as soap bubbles, and other light substances, rise in air, which shows, likewise, that it has weight. Under the name of atmosphere, it surrounds our globe, extending to a considerable distance from it, and accompanying it in its revolution round the sun; which indicates that it is connected with the earth by the general force of gravity, or attraction towards its centre.

Air is a fluid, because its parts are easily displaced.

Air has impulsive force; for when put into violent action, a current of it will carry away very heavy substances.

Air is perfectly transparent; that is, it permits the rays of light to pass through it; and therefore it is invisible.

Air is variable as to its degree of weight. Near the surface of the earth it is heaviest, and grows thinner and lighter in proportion to its distance from the earth.

As air has weight, like other fluids, it presses in every direction whatever bodies are immersed in it. This pressure is equal to a column of quicksilver, about 29 or 30 inches high. That is, a column of air, reaching to the extremity of the atmosphere, will support a column of quicksilver of equal diameter, at the height of

29 or 30 inches, as it will a column of water of equal diameter, at the height of 33 feet.

The quantity of the pressure of the atmospheric air is estimated to be not less than 2,232 pounds, upon every square foot of surface, or upwards of fifteen pounds upon every square inch. Computing, therefore, the surface of a man's body at 15 feet square, the whole pressure which it sustains is nearly equal to 33,480 pounds. By such a pressure, we should, undoubtedly, be crushed in a moment, if every part of the human body were not filled with air, or some other elastic fluid, the spring of which is strong enough to counteract that pressure.

But this pressure of the air answers many useful ends. It prevents the blood vessels in animals, and the sap vessels in plants, from being too much distended by the expansive power, which has a perpetual tendency to swell them out. It is owing to the gravity of air, that liquid substances remain liquid; for without that pressure, they would become vapour. Salts and oils remain united in air, but separate as soon as that fluid is extracted.

The absolute extent to which the atmosphere reaches from the earth, has not yet been determined. But the beginning and ending of twilight show, that the height at which the atmosphere begins to refract the beams of the sun, is about forty-four English miles; so that it is supposed to extend on all sides from the earth about fifty miles.

An instrument to show the different weight of the air, at different times, and at different dis-

tances from the earth's surface, was invented by an Italian, named Torricelli. He first showed, in the year 1645, that a column of atmospherical air may be made to balance a column of another fluid having the same base. To avoid the inconvenience of using a pipe 30 or 33 feet, the length of the column of water which the pressure of the air was found to sustain, he employed quicksilver instead of water; because quicksilver being much heavier than water, the pressure of air would support a column of that metallic fluid, proportionably shorter. By this experiment it was found that the pressure of the air which elevates water to the height of 32 feet, will not sustain a column of quicksilver above the height of 28 or 30 inches. Upon this idea was constructed the instrument called barometer or measurer of weight. It is nothing more than a glass tube with a bulb at one end filled with mercury. This is fastened to a piece of wood or metal graduated, in order to measure the rising or falling of the mercury, as it is pressed by the different weight of the air.

The thermometer, or heat measurer, is an instrument invented to show the different degrees of heat prevailing in air, water, or any other substance. Air, alcohol, and oil, have been successively employed as measures of heat; but quicksilver has been preferred to these, because it was found to be more regular in its expansions. A certain quantity of quicksilver is poured into a glass tube, which ends in a bulb or globe. It is so contrived that the part of the tube not filled with quicksilver, shall be empty of air, and

its opening is completely closed by heating that end of the glass tube with charcoal or a blow-pipe, so as that it may be twisted round; thus entirely excluding the external air. This operation is called hermetically sealing the tube. The glass tube being prepared in this manner, is attached to a graduated scale, which is made by first plunging the thermometer into a mixture of pounded ice or snow and sal-ammoniac; the point at which the quicksilver settles down, is marked O; which is the beginning of the scale. It is afterwards immersed in boiling water, and the point to which the quicksilver rises is marked 212°. The intermediate part of the thermometer is divided into an equal number of degrees. The quicksilver in the tube will rise or fall in proportion to the presence or absence of caloric in the surrounding medium.

Another machine, by which a great number of interesting experiments are performed, is the air-pump. It was invented in 1654, by Otto Gueric, a German, and by means of it a glass or any other vessel may be deprived of the atmospheric air, by which it had been filled. It pumps out the air by means of pistons working in brass trunks, or large tubes. A metal plate is connected with the barrels, by an orifice in its centre, over which is put a piece of wetted leather having a hole in it to correspond with the orifice in the plate. Upon this is inverted a glass bell, and under the bell is placed the substance or vessel from which the air is to be pumped out through a tube. When the air is exhausted from the inverted glass bell, it is fastened down so

tight to the plate by the external air, that it cannot be removed without great force, until the air is let into the bell again, when it is easily taken up.

The air-gun is an instrument which shows the elasticity and compressibility of air, in a very striking manner. In this instrument a quantity of air is condensed or pressed very close, by various contrivances, in such a manner, that the condensing power being suddenly removed, a bullet will be sent to a considerable distance, with little or no noise, but with great force, by the spring or elasticity of the air returning to its natural bulk. In this manner the elasticity of the air will drive a ball with such violence as to pierce an oaken board, half an inch thick, at the distance of 26 yards.

Balloons are machines filled with a gas considerably lighter than the atmospheric air, in consequence of which they rise in that air. In 1766, Cavendish discovered that inflammable air, or hydrogen gas, is seven times lighter than common air; and soon after this, Black made soap bubbles ascend by filling them with inflammable air. In 1783, two brothers, named Montgolfier, paper manufacturers, at Annonay, in France, caused a large bag to ascend to a very great height, by filling it with rarefied air, produced by burning straw and chopped wool. This gave the idea to the philosophers at Paris, of inflating a globe of silk with hydrogen gas. The globe, when filled, rose to the height of 3123 feet, in two minutes.

The first person who ventured to ascend into the atmosphere, in a car or boat attached to one of these machines, was Pilatre de Rozier, who afterwards lost his life by the balloon's catching fire. Since that period many persons have ascended to great elevations with balloons. The inflammable air balloon is now preferred to the Montgolfier, or rarefied air-balloon; because the latter is always in danger from the fire which must be attached to it, in order to rarefy the air within the globe. The balloon is generally made of silk, varnished with a solution of elastic gum. If the person carried up with it wish to mount higher, he throws out some ballast. If he choose to descend, by opening a valve he lets some of the gas escape gradually. The car, or boat in which the aëronaut sits, is generally suspended by a netting, which is thrown over the whole of the silken globe.

An instrument has been invented for measuring the quantity of rain that falls. This is called a rain-gauge. It consists of a funnel, whose diameter is twelve inches, attached to a tube of four inches diameter. In the tube is a floating graduated index, which rises as the rain falls into, and rises in, the funnel and the tube. By this instrument, the nine hundredth part of an inch of rain may be estimated.

Another instrument, called a hygrometer, is used for measuring the degrees of moisture. This is constructed of various materials, and in different ways. The most common and simple hygrometer, is a piece of whipcord, or catgut,

fastened at one end to a block of wood or metal, and stretched over several pulleys; while at the other end are a small weight and an index, which move up and down a graduated scale.

QUESTIONS.

What are the objects of the science of pneumatics? What are the properties of air? How is air proved to be material? How is air proved to have weight or gravity? Why is air said to be a fluid? How does it appear that air has impulsive force? Why is air transparent? Has the air different degrees of weight? What is the proportion of the pressure of a column of air, to that of a column of quicksilver? What is the pressure of the atmosphere upon the human body, and how is it that the great weight does not crush the human body? What are the beneficial effects of this pressure of the air? How far is the atmosphere supposed to extend from the surface of the earth? What is the barometer? What is the thermometer? What is the air-pump? What is the air-gun? What is the air-balloon? What is the rain-gauge? What is the hygrometer?

CHAP. XLII.

PNEUMATICAL EXPERIMENTS.

BODIES cannot move in the atmosphere without displacing a portion of it proportionable to their expansion. This requires force, and the resistance of the air always diminishes the velocity of bodies moving in it. This is the reason why light bodies, such as feathers, fall more slowly than bodies which have more bulk or weight, but less extension of surface. Their moving force is very small, and can, therefore,

displace a large quantity of air, only with a very small velocity. But if the same bodies be dropped in a vacuum, where there is no air to be displaced, they fall with the whole velocity competent to their gravity. Thus, a guinea and a feather being let fall in the exhausted receiver of an air-pump, reach the bottom at the same instant.

By means of the air-pump, the air can be completely extracted from a dry vessel, so as that the precise weight of the air which filled it, may be estimated. Dr. Hook found that 114 pints of air, weighed 945 grains, that one pint of water weighed 8 $\frac{7}{31}$ ounces; which gives for the specific gravity of air, $\frac{1}{860}$ very nearly. If a small beam be suspended within a receiver; to one end of which is attached a thin glass, or copper ball, closed in every part, and balanced by a small piece of lead hung on the other arm, and the receiver be then exhausted of its air; as the exhaustion takes place, the ball will gradually preponderate, that resistance being thus withdrawn, which supported it before; but as the air is readmitted, the ball will regain its equilibrium, the resistance being restored.

When the air is abstracted from the receiver, it is strongly pressed to the pump-plate, by the incumbent atmosphere; and it supports this great pressure in consequence of its circular form.

Place a small receiver, or cupping glass on the pump-plate of the air-pump, without covering the central hole, and cover the small, with a larger receiver. Exhaust the air from it, and then admit it as suddenly as possible. The outer

and larger receiver, which, after the exhaustion, adhered strongly to the plate, will be loosened by the readmission of the air, but the smaller receiver will be found still firmly fastened.

If a piece of wet bladder be placed over the top of a receiver, whose orifice is about four inches wide, and the air be exhausted from that receiver, the incumbent atmosphere will press down the bladder into the receiver, in a concave form, and finally burst it inwardly, with a loud explosion.

If there be formed two hemispherical cups of brass, with very flat thick brims, and one of them be fitted with a neck and stop-cock, the air may be pumped off from them, by screwing the neck into the hole in the pump-plate. The sphere may then be unscrewed from the pump, and it will require a very strong force to tear asunder the two hemispheres, thus attached to each other.

If the sphere, formed by this junction, be four inches diameter, it will require nearly 190 pounds to separate the attached hemispheres. This experiment was first made by Otto Guericke. His sphere was so large, that when the air was exhausted from the hemispheres, they could not be separated by the exertion of twenty horses.

Put an apparently empty bladder, of which the neck is firmly tied with a thread, under the receiver of an air-pump, and work the pump. The bladder will, then, gradually swell, till it be fully distended. Upon readmitting the air into the receiver, the bladder will gradually collapse into its former dimensions.

At the large end of an egg, there is a cavity between the shell and the white, which is filled with air. If a hole be made in the opposite end of the egg, and it be put under a receiver, and the air be exhausted, the air in the cavity of the egg will expand, gradually detaching the membrane from the shell, till it cause it to swell out, and give the whole, the appearance of an entire egg. In like manner, shrivelled apples, and other fruits, will swell in vacuo, by the expansion of the air contained in their cavities. If a piece of wood, a twig with green leaves, charcoal, or plaster of Paris, be kept under water in vacuo, a prodigious quantity of air will be extracted; and if the air be readmitted into the receiver, it will force the water into the pores of the body. In this case, the body will not swim in water, as before.

If a fish be placed in water, under the receiver, when the air is exhausted, the fish loses the power of ascending or descending, or remaining in equilibrio, by means of the air-bladder which sometimes bursts, in which case the fish sinks to the bottom.

If a cup of porous wood, containing mercury, be placed on the receiver of an air-pump, and the air be exhausted from under it, the external pressure of the atmosphere, will force the mercury through the pores of the wood, in a shower.

If the air be abstracted from a piece of dry wood, and it be then immersed in mercury, while the air is readmitted into the receiver, the mercury will be forced into all the pores.

Place a square phial under a receiver, and ex-

haust the air from it: then let the air suddenly into the receiver, and the pressure of the readmitted air will dash the sides of the phial to pieces.

Place a square phial, filled with air, and accurately corked, so that none may escape, under a receiver; exhaust the air from the receiver, and the elasticity of the air within the phial, being no longer compressed by external air, will burst the phial.

Put a lighted candle under a receiver; exhaust the air from the receiver. The candle will then be extinguished, and the smoke will fall to the bottom, which shows that combustion cannot be carried on without air, and that smoke ascends because it is lighter than air.

If an animal be placed under a receiver, and the receiver be exhausted of air, that animal will grow faint, and will die, if air be not readmitted in time; which shows that air is necessary to the support of animal life.

QUESTIONS.

What experiment shows the resistance of the air? How can the precise weight of a quantity of air be estimated? What experiments show the pressure of air? What experiment proves the elasticity of air, and its expansion? What experiments prove that air is necessary to combustion and to animal life?

CHAP. XLIII.

METEOROLOGY.

When, by natural or artificial means, water is made hotter than the air by which it is surrounded, the matter of heat having a constant propensity to diffuse itself equably through all substances with which it is in contact, spreads itself into that air, carrying with it particles of the water; thus forming what is called steam, or vapour. This operation is very gradual, until the water become heated to the boiling point, that is to the highest degree of which it is capable, when it goes on rapidly; and the continued application of heat, would change the whole of the water into steam. An urn, the iron of which is red hot, or a tea-kettle on the fire, affords a good example of this. By such a process, the sun raises water into the air, in the form of vapours.

The water, which, by the sun's heat, is converted into vapour, continues to ascend till it meets with colder air, which condenses it into clouds. Some vapours, ascending higher into the atmosphere, are frozen into snow; while others, which are condensed in the lower regions of the atmosphere, become mists. When these collections of vapours grow too heavy for the air to sustain, they descend; but the air opposing some degree of resistance to their descent, they are scattered into rain, if not frozen into hail or snow. Were it not for this interposition of the

air between us, and the water falling from a considerable height, a drop of rain might descend with dangerous momentum, and a hailstone might strike a fatal blow. Between the tropics and near the poles, where cold and heat exert their power in an excessive degree, meteors are seen in various terrifying forms, and the forces of air, fire, and water, combine to produce the most tremendous effects.

In the torrid zone, when what is to those regions, winter, commences about May, the atmosphere exhibits formidable meteoric appearances. Gloom takes place of fiery brightness, and the whole horizon appears wrapt in one dense mass of clouds. Thick fogs almost intercept the light of the sun. Then follows a continued succession of thunder storms, violent rains, and tempests of wind. When these cloudy terrors have ceased, meteors of another kind begin to exhibit themselves. Vapours of various sorts are raised by the intense sun beams darting upon stagnant waters. Bodies of fire, of different forms and magnitudes, are seen flashing through the air, diffusing around them surprising brilliance. The meteors of the polar skies are, also, very splendid and striking. Luminous circles round the moon; lunar rainbows, of a pale white, striped with grey; and the aurora borealis, or northern lights, stream over the heavens in varieties of colour, and fantastic shapes. Mock suns, and solar rainbows, of pale white, edged with stripes of dusky yellow, are often seen reflected from the bosom of a frozen cloud.

Currents of air, supposed to be occasioned by the unequal rarefaction of the atmosphere, by the operation of heat, are called winds.

The winds are arranged in three general classes.

First. General or permanent winds; or those which blow always in nearly the same direction. In the Atlantic and Pacific oceans, under the equator, and on each side of that circle, to the latitude of 28°, the wind blows almost always easterly. More northward of the equator, the wind generally blows between the north and east. More to the south of the equator, its common direction is between the south and east. These general winds have the name of trade-winds.

The periodical winds are those which blow in a certain direction, for a certain time; and at particular seasons, change, and blow, for an equal space of time, from the opposite point of the compass. These are named monsoons.

Variable winds are those which blow without any certain rule.

Hurricanes, or tornados, are tremendous storms of wind, rain and thunder, attended with a furious swelling of the sea, and sometimes accompanied by earthquakes.

The harmattan is a wind which blows periodically, from the interior parts of Africa, towards the Atlantic ocean. It is accompanied by a thick haze, so as to obscure the sun. Extreme dryness is another property of this wind. During its continuance, no dew falls. Vegetables are withered, and the grass becomes dry, like

hay. It shrivels up the covers of books, spoils furniture, and scarifies the skin; but it stops epidemic disorders, and relieves from intermitting fevers. The sirocco, or Levant wind, which is frequently felt in Sicily, is extremely hot, and very prejudicial to animal and vegetable health.

The samiel, or simoom, is the most destructive of all winds. It blows in the sandy deserts of Asia and Africa, killing instantly whatever animal is so unfortunate as to inhale it. It appears like a purple haze, sailing through the air with great celerity.

Water-spouts are, probably, caused by a sudden vacuum taking place, owing to a local rarefaction of air. This creates a suction which carries up with it whatever happens to be within the vortex; water, or any other substance. When this is water, it assumes the form of an inverted cone, which, when it bursts and falls, is very dangerous.

Mariners at sea, when they see this phenomenon, frequently fire a great gun, that the concussion of the air may break the approaching water-spout, before it reach their vessel.

Land and sea breezes in the tropical climates, may be regarded as partial interruptions of the general trade-winds.

The earth being heated during the day, the air above it is rarefied, and thus, in the afternoon, a breeze sets in from the sea, which is less heated at that time than the land. On the other hand, during the night, the earth loses its surplus heat, while the sea continues more even in its temperature. Thus, towards morning, a

breeze regularly blows from the land towards the sea, the air in contact with which, is then warmer, and therefore more rarefied, than the air which is in contact with the land.

QUESTIONS.

What is vapour, or steam? What are the causes of rain, of hail, of snow? In what reigons of the globe are meteoric phenomena most frequently seen? What are the meteoric appearances in the torrid zone? Of what kind are the meteors of the polar skies? What are winds? What are trade-winds? What are monsoons? What are variable winds? What are tornados? What is the harmattan? What is the sirocco? What is the simoom? What is a water-spout? What are land and sea breezes?

CHAP. XLIV.

ARCHITECTURE.

CIVIL ARCHITECTURE.

The origin of architecture must be of very high antiquity; for men must have soon felt the necessity of sheltering themselves from the inclemency of the changing seasons; and when they had begun to build houses for that purpose, they would have proceeded gradually to consult conveniency, and, finally, ornament.

Among the ancient Egyptians, Assyrians, and Persians, architecture was carried to an astonishing length; but its principal character was that of massive solidity, and magnificent gran-

deur. Of the former, the pyramids, and of the latter, the ruins of Persepolis, exhibit striking proofs.

The largest of the pyramids is nearly 500 feet high, and contains 313,590 solid fathoms. It is constructed of enormously large stones, some of which are thirty feet long, four feet high, and three feet broad; and this huge pile was coated over with square flags of marble.

The remains of the grand staircase of the palace of the Persian monarchs, at Persepolis, consists of ninety-five steps of white marble, so broad that twelve horses might easily ascend them abreast. Neither the ancient Assyrians, nor Babylonians, knew the method of raising arches; and their buildings were destitute of taste: their columns were ill proportioned, and their capitals were badly executed. This was observed by the Greeks, who quickly established a more elegant style of architecture.

The Romans borrowed their architecture from the Greeks; and the ruins of their temples and public edifices show that they nearly, if not quite, equalled their instructors.

The ancient Gothic architecture seems to have been intended rather to astonish by magnitude, than to please by just proportions.

The modern Gothic, or Saracenic style is distinguished for the lightness of its work, the boldness of its elevations, the delicacy, profusion, and extravagant fancy of its ornaments. Its pointed arches and columns, consisting of distinct light shafts, are evidently imitations of

clumps of trees growing closely together, and disposed in avenues forming overhanging arches.

The art of building houses, bridges, churches, and public edifices, is styled Civil Architecture.

The art of erecting castles, forts, and walls, for defence, is called Fortification, or Military Architecture. The art of constructing ships and boats is Naval Architecture.

Proportion, solidity, adaptation to particular purposes, and ornamental beauty, are the chief requisites of good architecture. The principal ornaments used in architecture are, five orders of columns, pediments, arches, and ballustrades.

There are five orders of columns; the Tuscan, the Doric, the Ionic, the Corinthian, the Composite.

Each order is made up of three parts; the pedestal, the column, and the entablature.

The pedestal consists of the base or plinth, the dado or dye, and the cornice. The use of the pedestal is to raise the column to a proper height, and to give it a greater appearance of firmness.

The column consists of a base, a shaft, and a capital.

The entablature consists of an architrave, a frize, and a cornice.

The term plinth is derived from the Greek name of a flat stone, on which columns are supposed to have stood in the infancy of architecture.

The dado, or dye, is so called from its being in a cubical form; and the cornice takes its name from the Latin for a crown or summit.

The base of the column is its lower part or foundation; the shaft is its middle or stem; the capital is its summit. The covering of the column is called its abacus.

The architrave is the chief support of the whole entablature. Its name is derived from two Greek words, signifying principal beam.

The frize is the large flat facing of the architrave, frequently ornamented with the figures of leaves, flowers, and animals.

The cornice is the summit of the whole.

The Tuscan is the most solid and simple of all the orders. It has but few parts; it pretends to no ornament; and is so constructed for strength as to support the greatest weight.

Next in strength and simplicity to the Tuscan, is the Doric order. As this is the most ancient of all the orders, it retains more of the structure of the primitive huts of mankind, its frize representing the ends of joists, and its cornice the rafters. In most of the antiques, the Doric column is without a base. In the profile of the theatre of Marcellus, the frize is adorned with roses, bull's heads, and a garland of beads. The Ionic order is of a more slender make than the Tuscan or the Doric. Its appearance is simple, yet graceful and majestic. Its ornaments are few. The shaft of the column may be either plain or fluted. The ornaments of the capital must correspond with the flutings of the shaft.

The Corinthian order.—The proportions of this order are very delicate. It is divided into a variety of parts, and enriched with a profusion

of ornaments. The most complete model of the Corinthian order is generally allowed to be in the three columns in the Campo Vaccino at Rome, the supposed remains of the temple of Jupiter Stator. If the entablature be enriched, the shaft may be fluted. In most of the remains of ancient architecture at Rome, the capital of this order is adorned with olive leaves.

The Ionic, Doric, and Corinthian, are the three Grecian orders.

The Composite order is a species of the Corinthian, but admitting greater extent and variety. The ancients do not appear to have attached any particular form of entablature to this order. Sometimes the cornice is plain, as in the temple of Bacchus; and sometimes it is ornamented very little differently from the Ionic, as in the arch of Septimius Severus. The acanthus leaf is predominant amidst its ornaments.

Pilasters differ from columns only in their being square instead of round. They are frequently employed in churches, galleries, and halls, to save room, as they seldom project more than one quarter of their diameter beyond the solid wall, and, consequently do not occupy so large a space as columns.

Attics are square pillars, with their cornices. The Athenians invented them to conceal the roofs of buildings, which was a great object among them. Attics, therefore, serve as a kind of crown to an edifice.

Besides columns and pilasters, human figures are sometimes used to support entablatures in edifices. The male figures are called Persians,

and the female, Carians, or Caryatides. The ancients made frequent use of Persians and Caryatides, diversifying them by numerous and various attitudes. The Caryatides are clothed in Asiatic robes, and never much exceed the natural human size. The Persians are armed figures, frequently of gigantic grandeur.

Colonnades are rows of columns supporting one common entablature, or flat or arched ceiling.

Arches are very useful as well as ornamental in architecture. They were used for triumphal entrances, gates of cities, and palaces; and are the strongest supports of bridges, aqueducts, and extensive roofs. They are so constructed, that the stones of which they are composed keep one another in their places by proportionate pressure, and form a certain arc, or segment of a circle, in the middle of which is a large stone, on which the parts on each side of it rest, and which is, therefore, called the key-stone of the arch.

A Pediment is a kind of roof, of a triangular or circular form, used as a covering to doors, gates, windows, niches, &c.

Balustrades are series of short pillars, called balusters, of various figures, either cylindrical, like columns, or quadrangular, or swelling out in the middle, and supporting a common entablature. They are, sometimes, merely ornamental, and sometimes useful, as when they are employed in stair-cases, placed before windows, or inclosing terraces.

QUESTIONS.

What is architecture? What were the characteristics of the ancient Egyptian, Assyrian, and Persian architecture? What is the style of the Grecian and Roman architecture? What is the character of the ancient Gothic architecture? What is the style of the modern Gothic or Saracenic? What is civil architecture? What is military architecture? What is naval architecture? What are the chief requisites of good architecture? What are the principal ornaments used in architecture? What are the five orders of columns? What are the component parts of each order? What is the pedestal? What is the base, the shaft, and the capital, of the column? What is the cornice? What is the entablature? What is the architrave? What is the frize? What is the plinth? What is the Tuscan order? The Ionic? The Doric? The Corinthian? The Composite? What are pilasters? What are attics? What are colonnades? What are Persians and Caryatides? What are arches? What is a pediment? What are balusters and balustrades?

CHAP. XLV.

ARCHITECTURE—continued.

NAVAL ARCHITECTURE — FORTIFICATION.

THE art of ship building must have been very rude and imperfect in its infancy, like almost all other arts. The first attempts of men, to convey themselves over the surface of the waters, were, probably, by means of rafts, or pieces of wood, or other floating substances, connected together. By raising sides to those rafts, for the sake of security, they became boats; and by gradual enlargement, and various improvements, suggested from time to time, by convenience and safety,

those boats became ships with the covering of decks, and masts and sails.

Ship is a general name for vessels covered with decks, and furnished with masts and sails; but is commonly applied by sailors to such as have three masts.

The mast in the front of the ship is called the foremast; that in the middle, the mainmast; and that in the hind part, the mizzen mast.

Each mast is composed of three parts; the lower-mast, the top-mast, and the top-gallant mast.

The lower part of the vessel, which is under water when laden, is called the hold.

The upper works, which are usually above the water when the ship is loaded, are named the dead works. During the building of a vessel, she is supported by a number of solid blocks of timber, placed at equal distances, and parallel to each other. In that situation the ship is said to be upon the stocks.

The first piece of timber laid down upon the stocks, is a horizontal beam, called the keel, which, at one end, is let into an upright piece of timber called the stern-post, and at the other end is fastened into another upright post, named the stern. From the keel rise curved pieces of wood, called timbers, which are connected to a curvilinear frame above, at whatever height the architect intends to make the sides of his vessel.

The hinder part of the ship is called her stern, and contains the cabins and other accommodation rooms, for the captain, the officers, or passengers.

To the sternpost are fixed iron clamps and rivets to hold the rudder, a kind of large plank, placed vertically and moveably, by whose movement to one side or the other, the ship is turned like a door on its hinges.

The stem is a circular piece of timber in the front of the ship, into which her sides are inserted. The outside of the stem is commonly marked with a scale of feet, according to its perpendicular height from the keel, to ascertain the draught of water at the fore part, when the ship is in preparation for a voyage.

Ships have decks or stories, one or more, according to their size and the purposes for which they are intended.

The part of the upper deck which is over the stern, is called the quarter-deck.

The middle part of the vessel destined for the cargo, provisions, &c. is called the hold.

Yards are long pieces of wood attached transversely to the masts; by which the sails are suspended.

There are a great number of sails of various shapes and sizes, by the action of the wind upon which, the vessel is impelled through the water. The principal sails are the main-sail, fore-sail, and mizzen, which are the largest and lowest sails on their several masts; topsails, which are large square sails of the second degree in height and magnitude.

The ropes and tackles by which the sails are hoisted up or lowered, extended or reduced, are called haliards, clue-lines, and clue-garnets.

Shrouds are thick ropes stretching from the

mast-heads downwards to the outside of the ship, serving to support the masts. They are used as rope ladders, by which the seamen ascend and descend.

Wales are an assemblage of strong planks, which envelope the lower parts of the ship's sides; wherein they appear like a range of hoops separating the bottom from the upper works.

The anchor is a weighty instrument of iron, which being let down into the water holds the ship fast, by its weight penetrating deeply into the mud or sand at the bottom. It is composed of a straight bar, having a ring at one end, and at the other a curbed piece of iron barbed at its ends. A very large and strong rope fixed to the ring of the anchor, is called the cable.

A large roller used to wind in the cable, and heave up the anchor, is called the windlass. This is turned about vertically by a number of long bars or levers, inserted into holes made in it for that purpose.

Caulking a ship, is the driving of oakum, or the substance of old ropes untwisted, into the seams of the planks, to prevent the water entering through those interstices.

The oakum is then covered with melted pitch or resin.

The bottom of ships is generally covered with a mixture of tallow, brimstone, tar, and resin. This is called paying the ship.

The bottom of ships is sometimes covered with copper, to make them sail better. Ships are generally built of oak timber, because it is our

strongest wood, and because it is not so liable to splinter as the wood of other trees.

The masts are commonly made of fir or pine wood, on account of its straightness and lightness.

The ship, when finished, is launched into the water, by means of a frame of well greased planks, called a cradle; in which, when the blocks and wedges that supported and held her back are removed, she glides gently down.

Ships of very large size are usually built in dry docks; and when they are finished, the gates are thrown open, and the tide entering floats them out.

MILITARY ARCHITECTURE, OR FORTIFICATION.

This is the art of putting a town or other place in such a posture of defence, that each one of its parts defends, or is defended by some other part. This is effected by means of ramparts, parapets, moats, and other bulwarks; so that a small number of men, occupying such a fortification, may resist for a long time the attacks of a much greater number.

A regular fortification is built in a regular polygon, the sides and angles of which are all equal.

An irregular fortification is that whose sides and angles are not uniform, equidistant, or equal.

A bastion is a pentagonal figure, four of whose sides are walls, and the fifth opened inward towards the place defended.

A straight wall joining one bastion to another, is called a curtain.

A given space within the external face of the wall of a bastion or curtain, is called the rampart.

The rampart is elevated more or less above the level of the place, from ten to twenty feet, according to the ground.

The parapet is a part of the rampart elevated six or seven feet above the rest, to cover the troops who man the rampart from the fire of the enemy.

The banquette is an eminence, two or three feet higher than the rampart, and three or four feet lower than the parapet; so that the soldiers may stand upon it and fire over the parapet.

Crown-works, horn-works, and ravelins or half-moons, are smaller fortifications advanced before the principal fortification.

A covered way is a passage for the soldiers to go from one part of the fortification to another, protected from the enemy's shot.

The glacis is the sloping external side of the wall and of the covered way.

At the external base of the wall is generally a wide and deep ditch; over which the soldiers of the garrison pass by draw-bridges.

QUESTIONS.

What was probably the rise of naval architecture? What is a ship? What are the names of the three masts? Of what parts is each mast composed? What is the hold of a vessel? What are the dead works? When is a ship said to be on the stocks? What is the keel? What is the stem? What is the stern? What are the timbers? What is the rud-

der? What is the quarter deck? What are the yards? What are the sails? What are haliards, clue-lines, and clue-garnets? What are the shrouds? What are wales? What is the anchor? The windlass? What are caulking and paying a ship? Of what wood are ships generally built? Of what wood are the masts commonly formed? How are ships launched? What is military architecture? What is a regular fortification? What is a bastion? What is a curtain? What are horn-works, crown-works, ravines, or half-moons? What is a covered way? What is a glacis? What is a rampart? What is a parapet? What is a banquette?

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